

Using CMIP5 retrospective predictions of Atlantic variability to assess the skill of future forecasts



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NOAA/GFDL

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Motivation

- Increasing demand for climate projections on time scales of one or two decades and on regional spatial scales (e.g. for water resources, agriculture, fisheries, insurance)
- Concerns about the possibility of abrupt climate changes

Motivating examples:

1 -Rapid decadal-scale loss of Arctic sea ice: July 2012 minimum

2-US drought: summer 2012

3-Atlantic hurricane activity, increased frequency?

For each of these events, how much was a response to radiative forcing? How much was internal variability? Could they have been predicted?

Goal: testing retrospective predictions in a mechanistic sense to assess the skill of future forecasts: detection/attribution of climate changes.

Predictions on decadal time scales can be of potential use for longer projections

GFDL decadal prediction system/Experimental design

Past climate projections focused solely on the response to radiative forcing changes.

Key question: Can we produce better predictions if we use information describing the initial state of the climate? Part of CMIP5 and IPCC AR5

Model:

Currently use of CM2.1 model (2°atm, 1°ocean, Delworth et al. 2006)

Initial conditions:

Ensemble Coupled Data Assimilation (ECDA) reanalysis (Zhang et al. 2007)

- .Atmosphere NCEP reanalysis (T,u,v,ps)

- .Ocean XBT,CTD, satellites,Argo

- .Radiative forcing GHG, solar, aerosols,volcanoes

Initialized runs

10 members ensemble, starting every year from 1960-2012, run for 10yrs (total of more than 5000 model years). Use observed estimates of radiative forcings 1960-2005, RCP4.5 thereafter

Uninitialized runs:

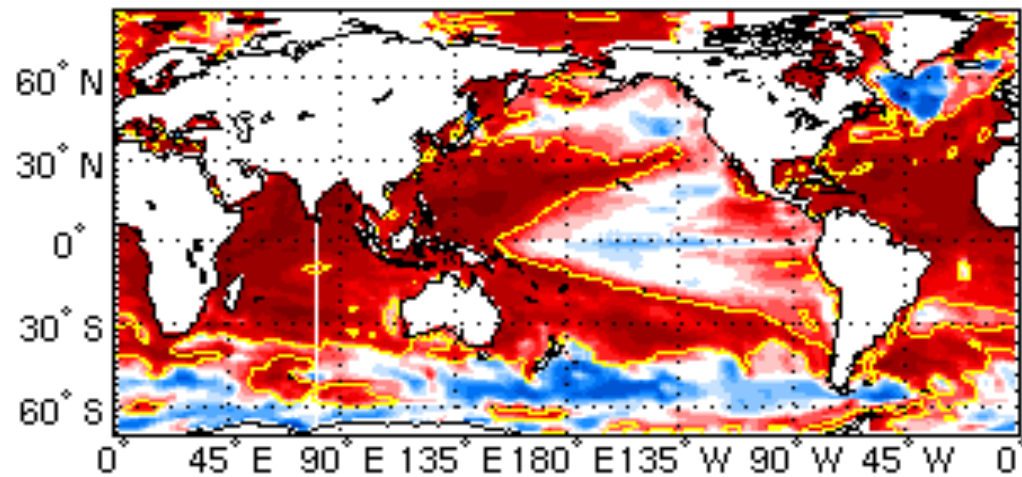
10 members ensemble, from 1861-2040. Use observed estimates of radiative forcings 1960-2005, RCP4.5 thereafter

Model outputs available at

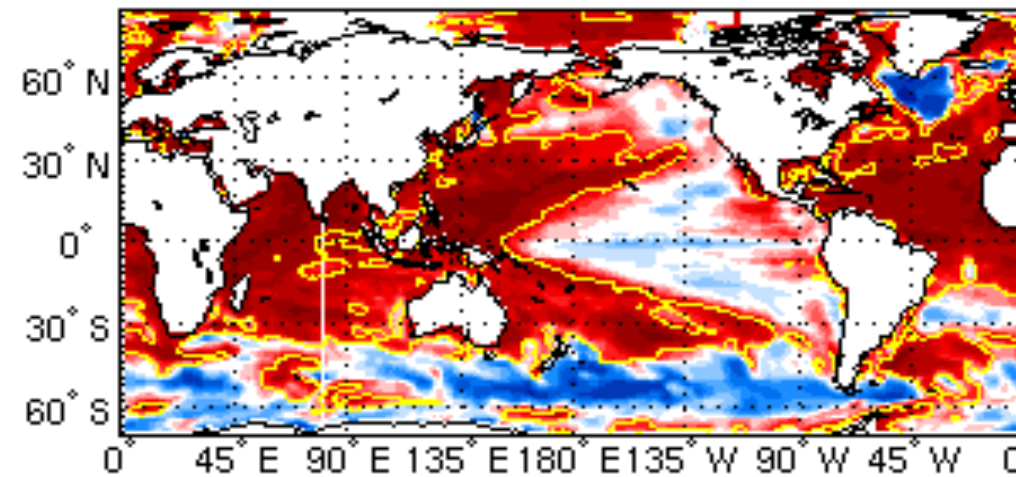
<http://nomads.gfdl.noaa.gov:8080/DataPortal/cmip5.jsp>

Results: SST anomaly correlations

GFDL Year 2-5 (Obs= GFDL SST)
ACC:Uninitialized Hindcast

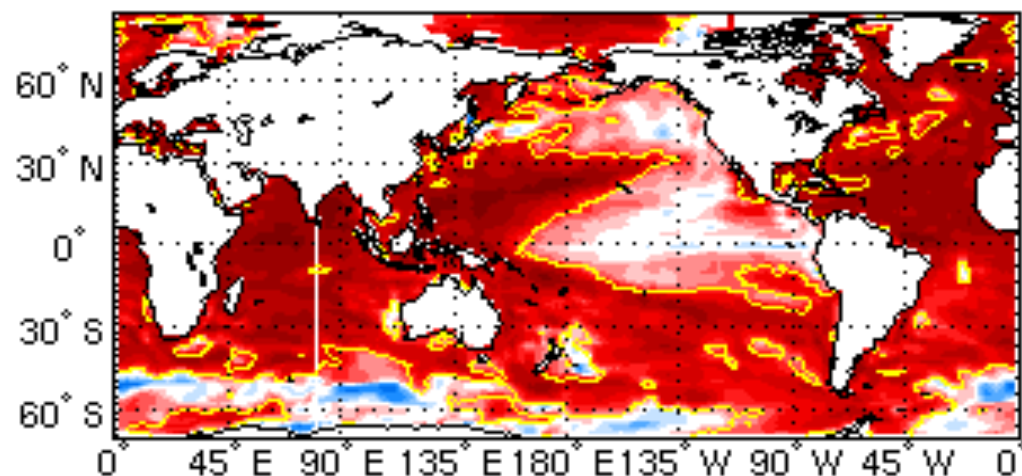


GFDL Year 6-10 (Obs= GFDL SST)
ACC:Uninitialized Hindcast

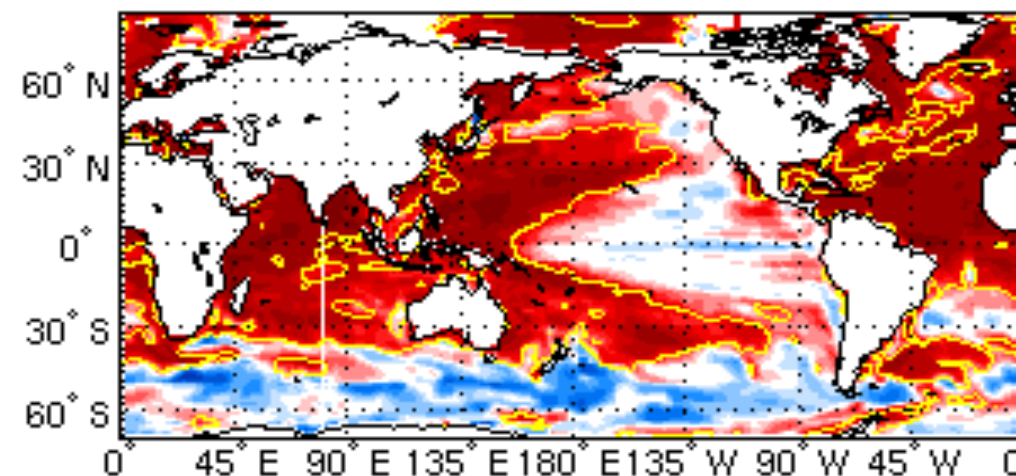


Red: skill due to forcing

ACC:Initialized Hindcasts

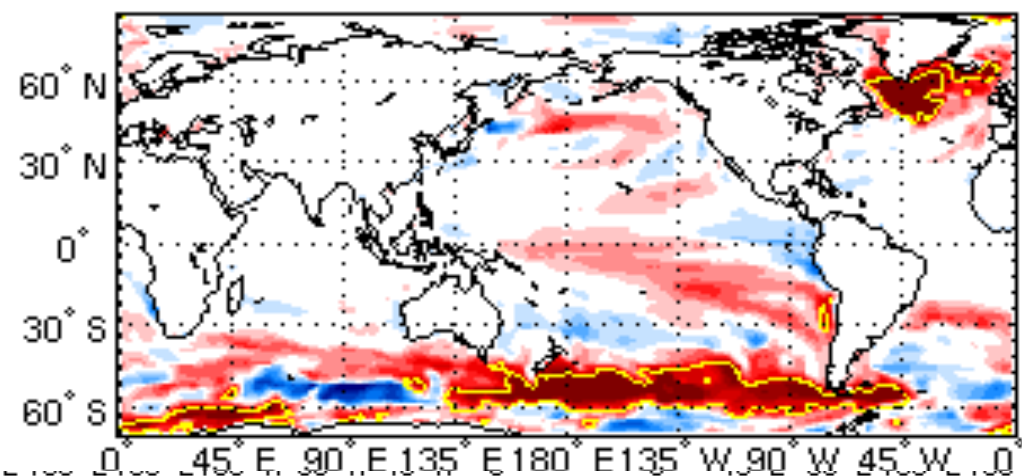


ACC:Initialized Hindcasts

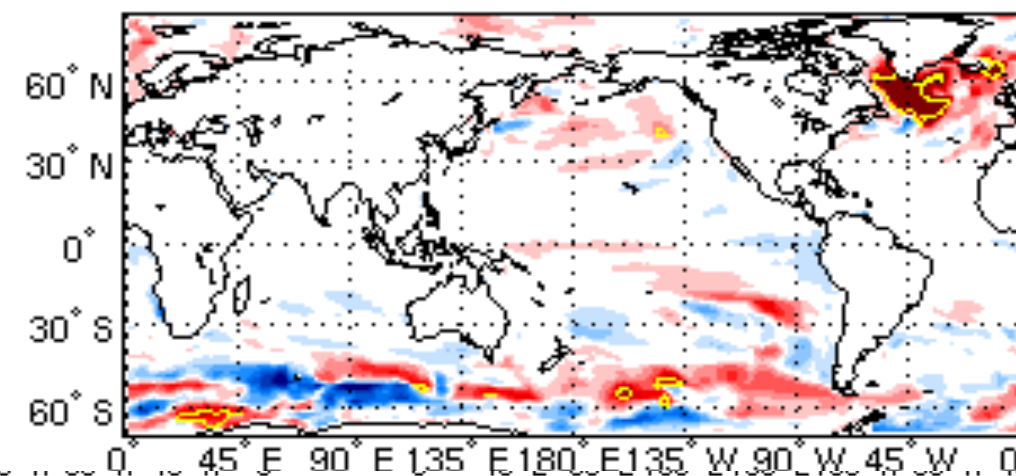


Red: skill due to both initial conditions and forcing

Diff. Initialized - Uninitialized

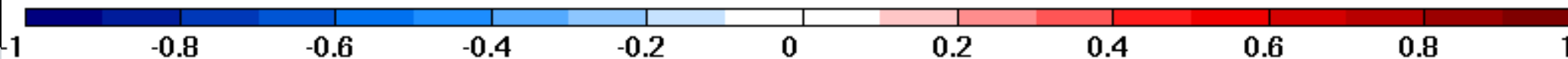


Diff. Initialized - Uninitialized

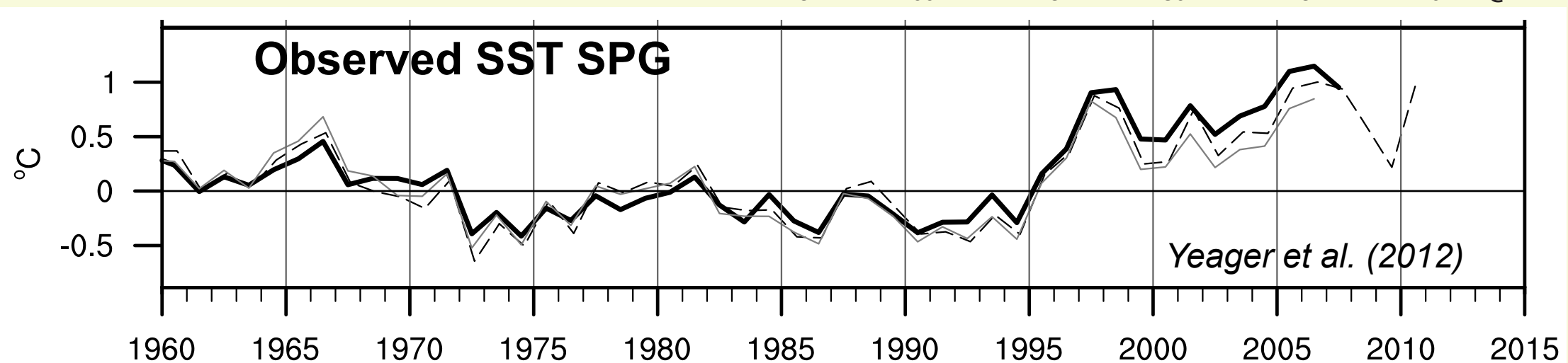
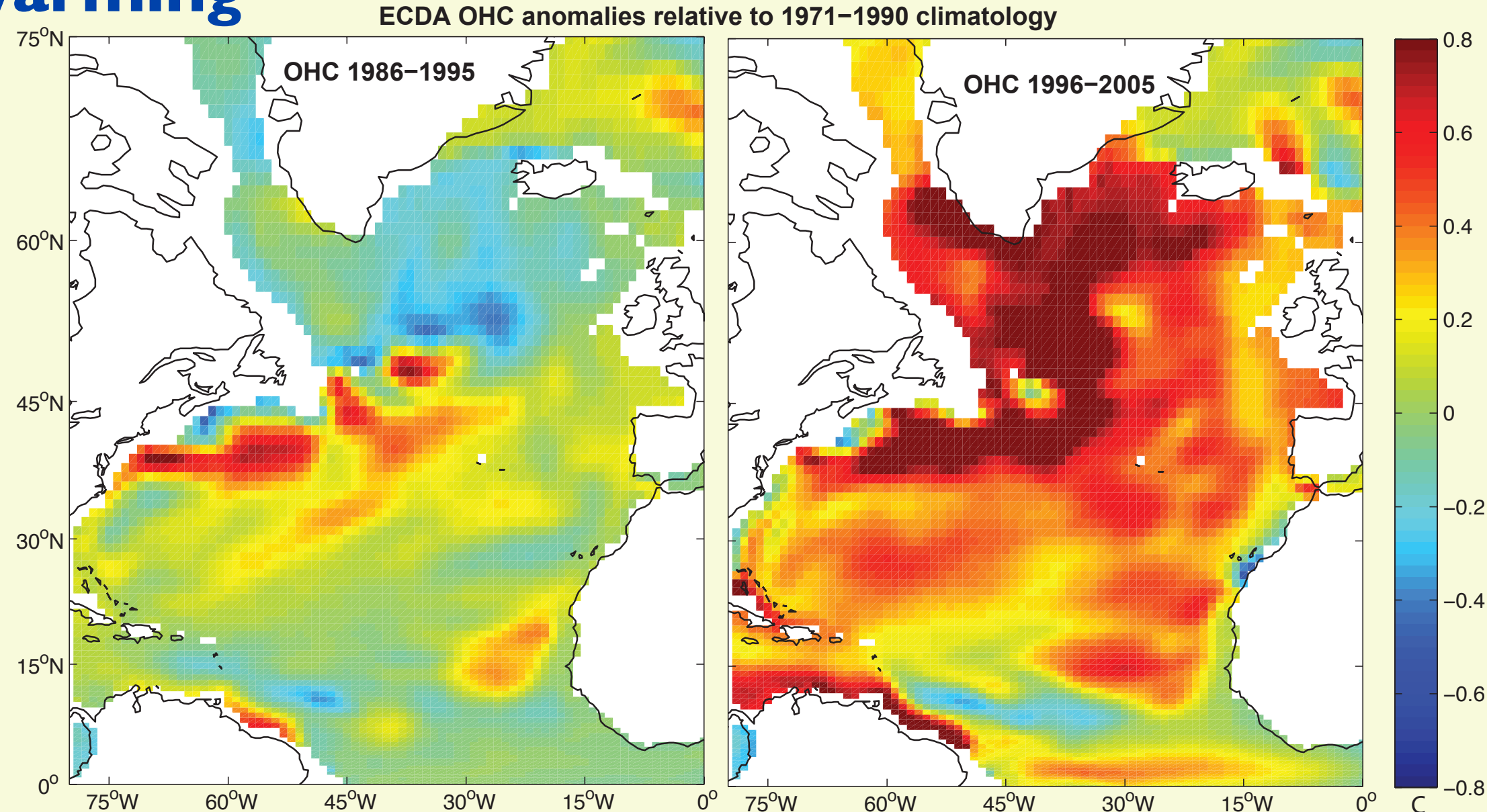


Red: improvement due to initialization

Rosati et al. (2012, submitted)
Yang et al. (JOC 2012)

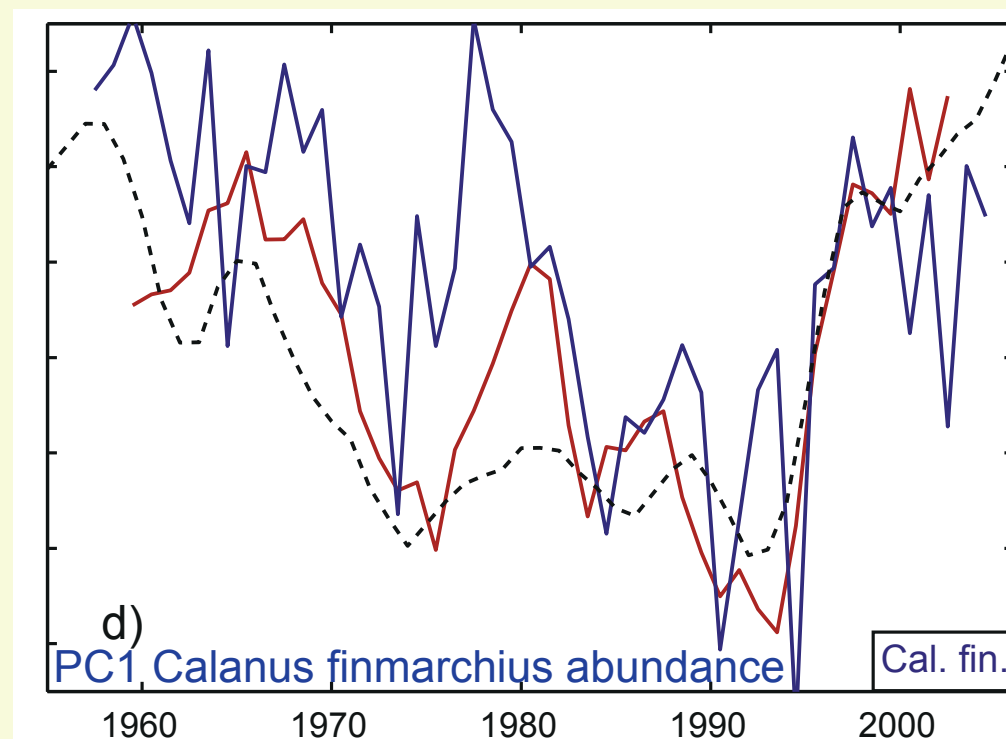
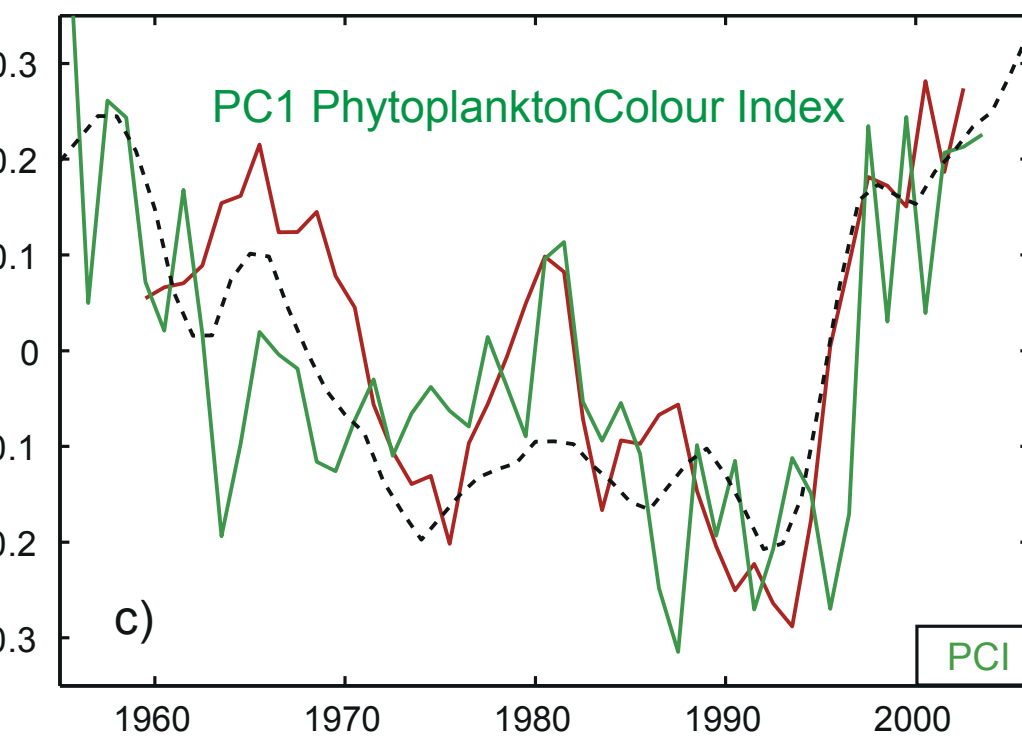
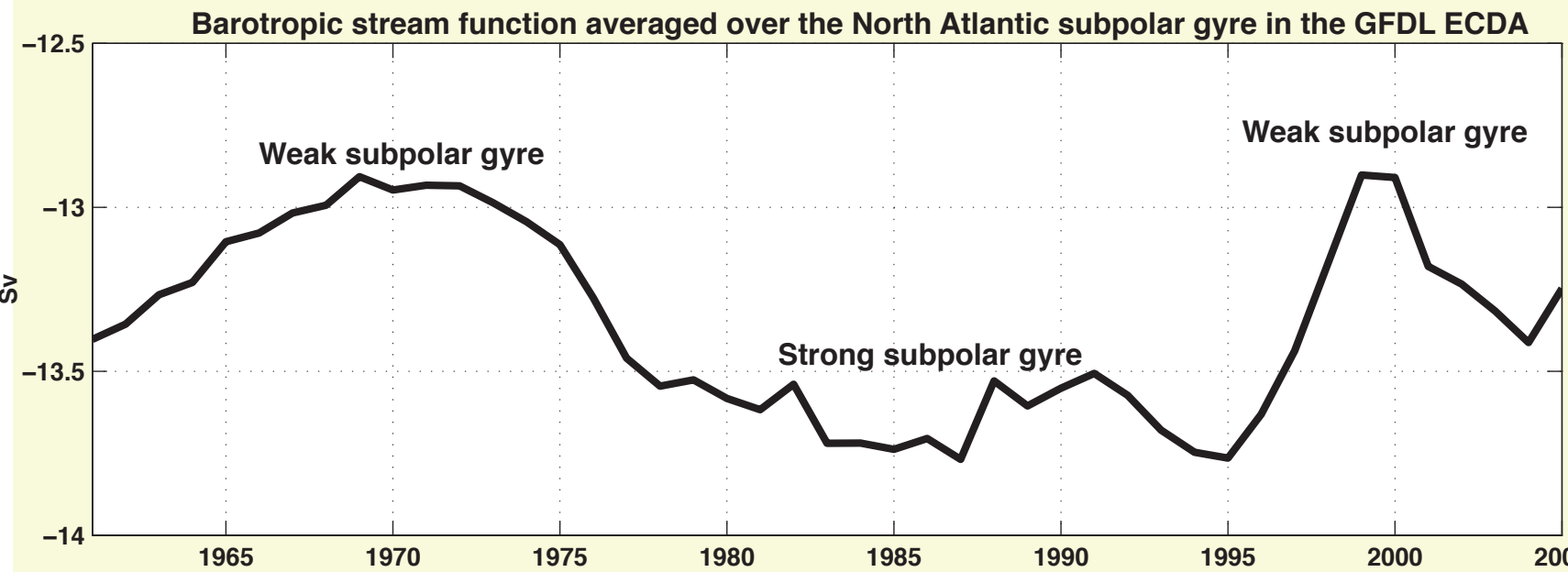
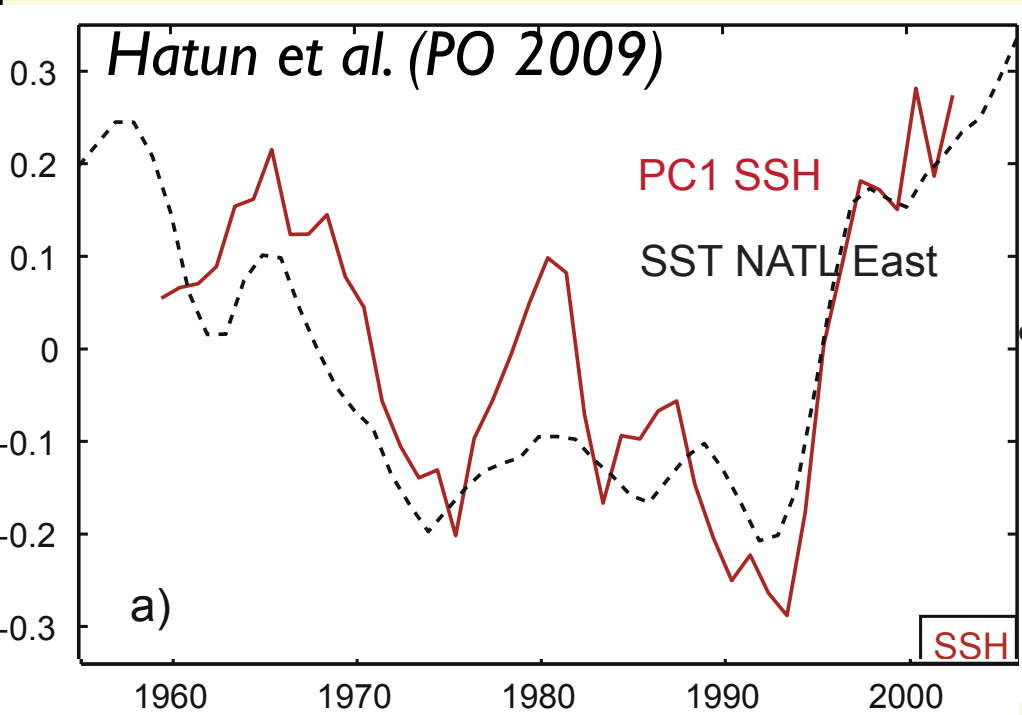


An interesting case study: the 1995 subpolar gyre abrupt warming



Observed warming of the North Atlantic subpolar gyre after 1995

Climate shift detected in marine ecosystems



Blue whiting



Pilot whales

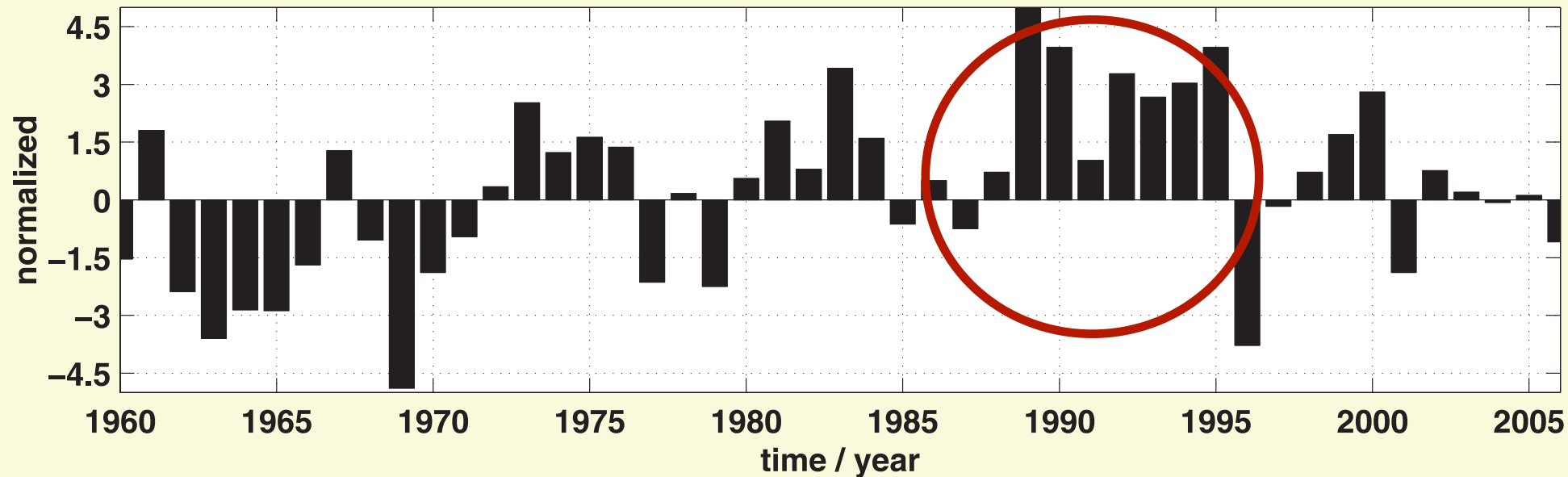


Shift in subpolar gyre strength => shift in phytoplankton & zooplankton abundance => impact on fish migration/activity => impact on fisheries

What happened in 1995?

Observed NAO index

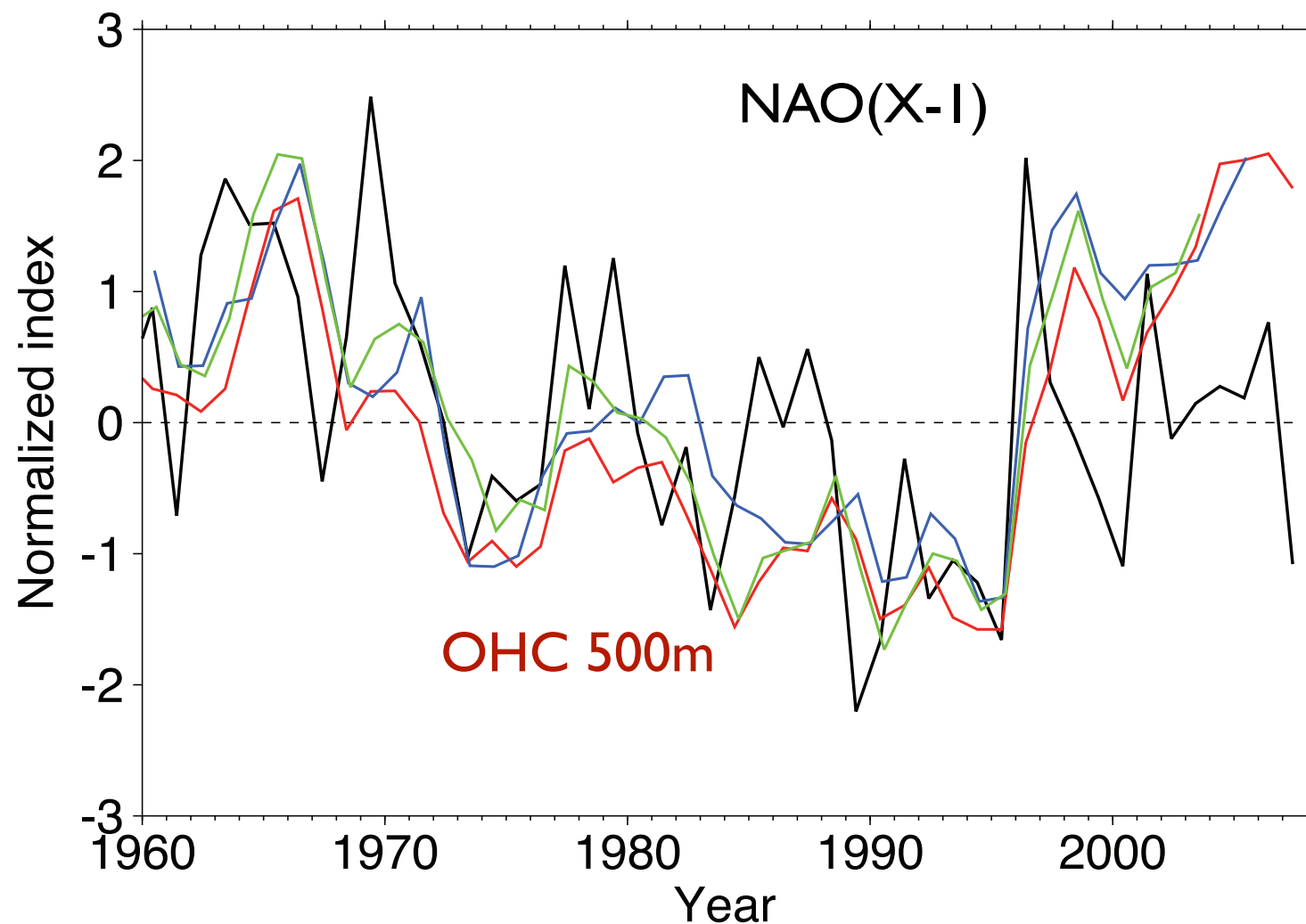
from Lohmann et al. (2009)



**Instantaneous
response to NAO
decline?**

**Or lagged
response to
persistent
positive NAO?**

AMOC



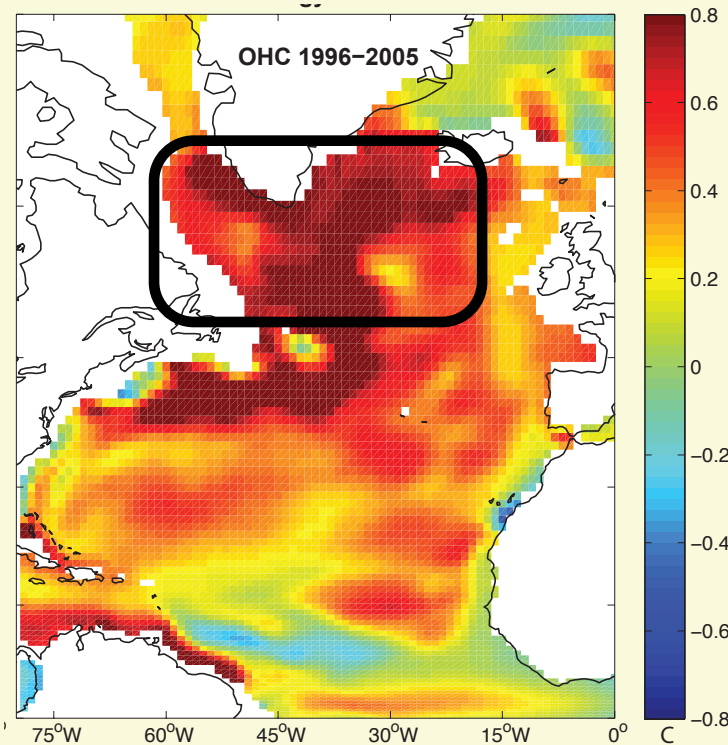
Robson et al. (JOC 2012)



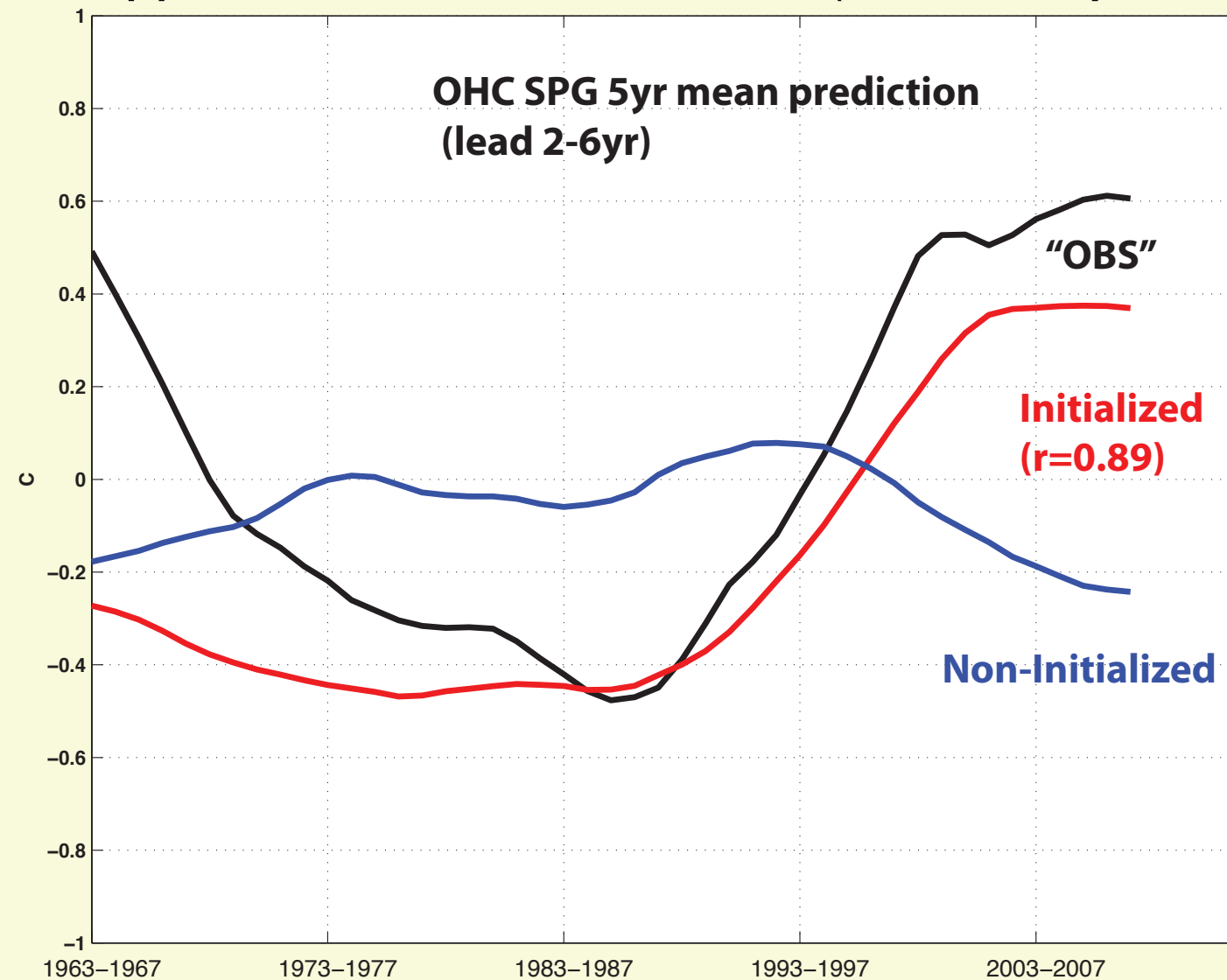
Srokosz et al. (BAMS, 2012)

Results from GFDL predictions: the shift is probably not a forced signal

SPG box (50W-10W;50N-65N)



Upper 600m OHC anomalies (seasonal cycle removed)

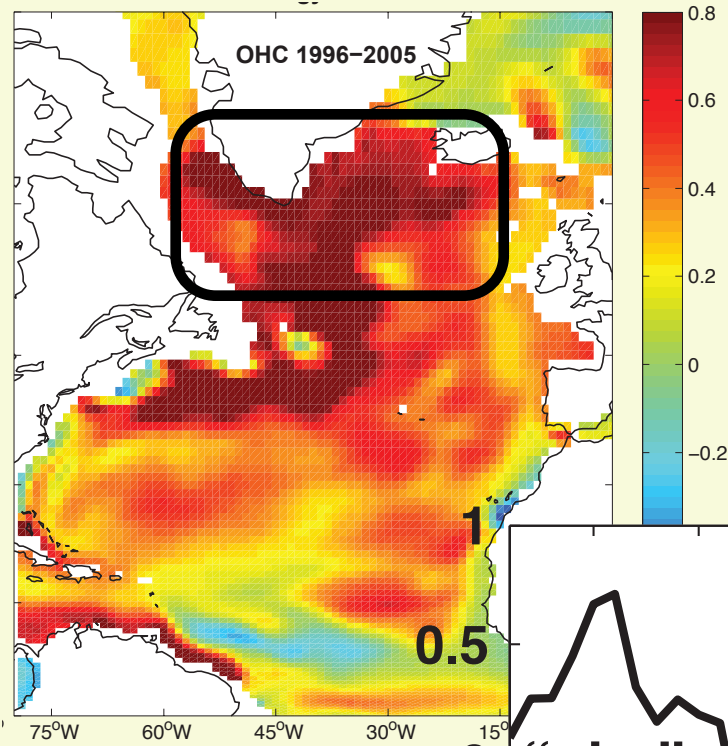


Poor skill in the uninitialized experiments. Suggests an internally driven mechanism rather than radiatively forced

Observed variability of North Atlantic ocean temperature dominated by the mid 90's shift.

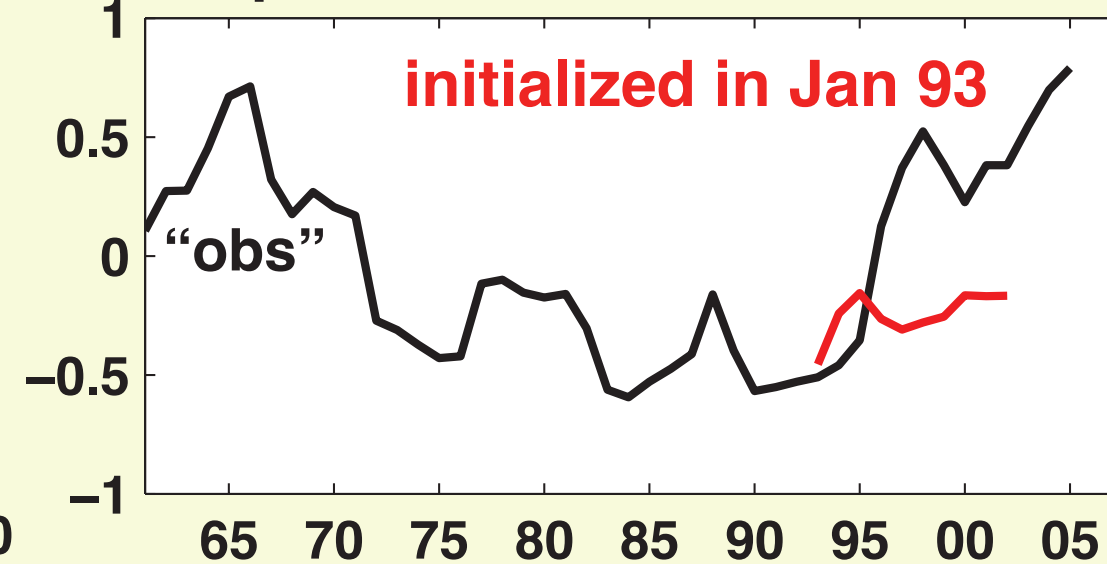
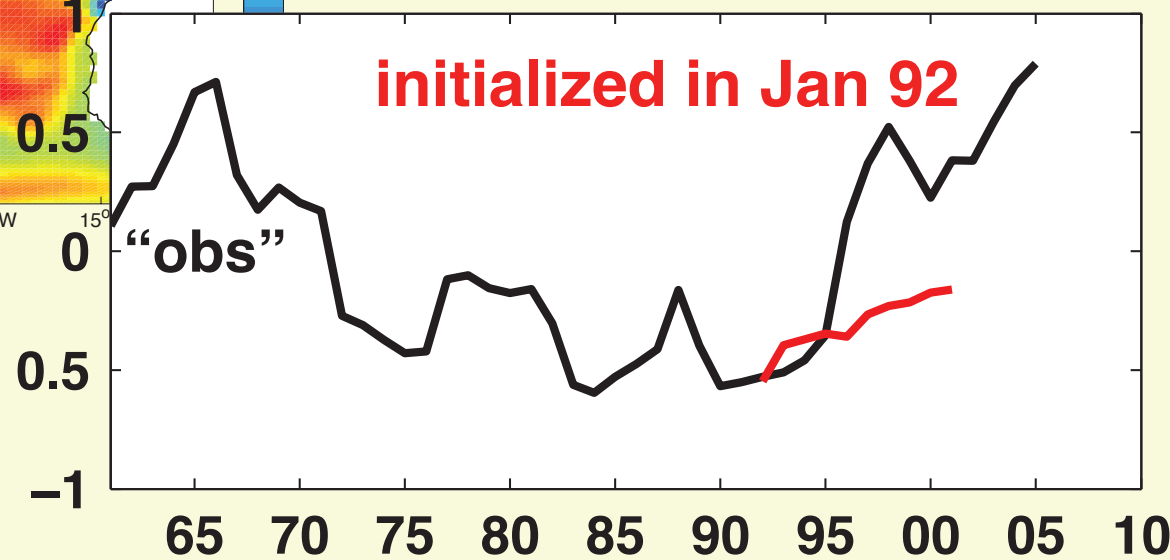
Is the good skill in the initialized experiments a result of predicting the shift?

Results of the initialized predictions

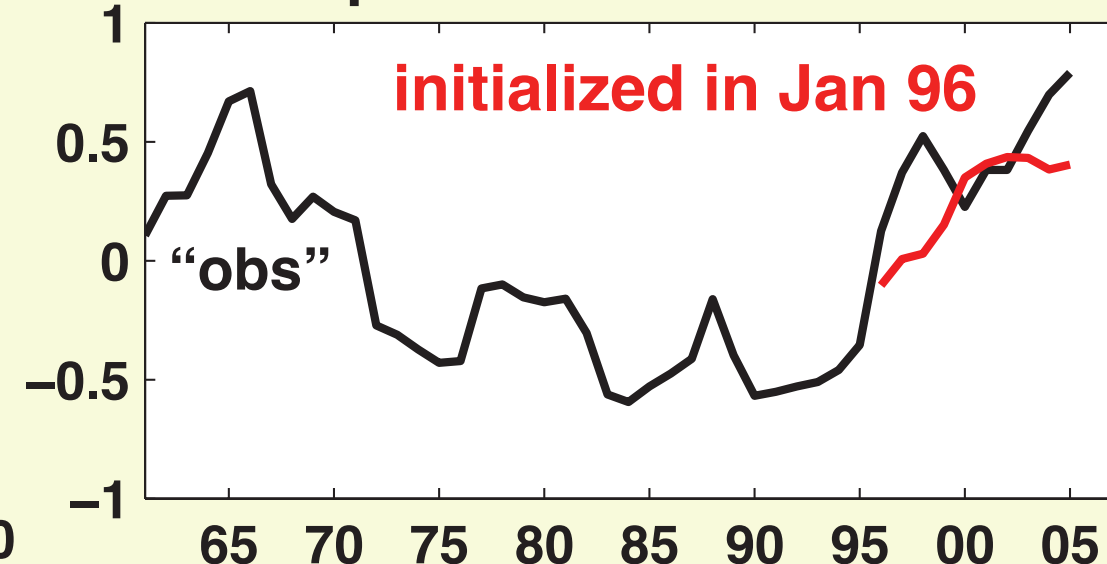
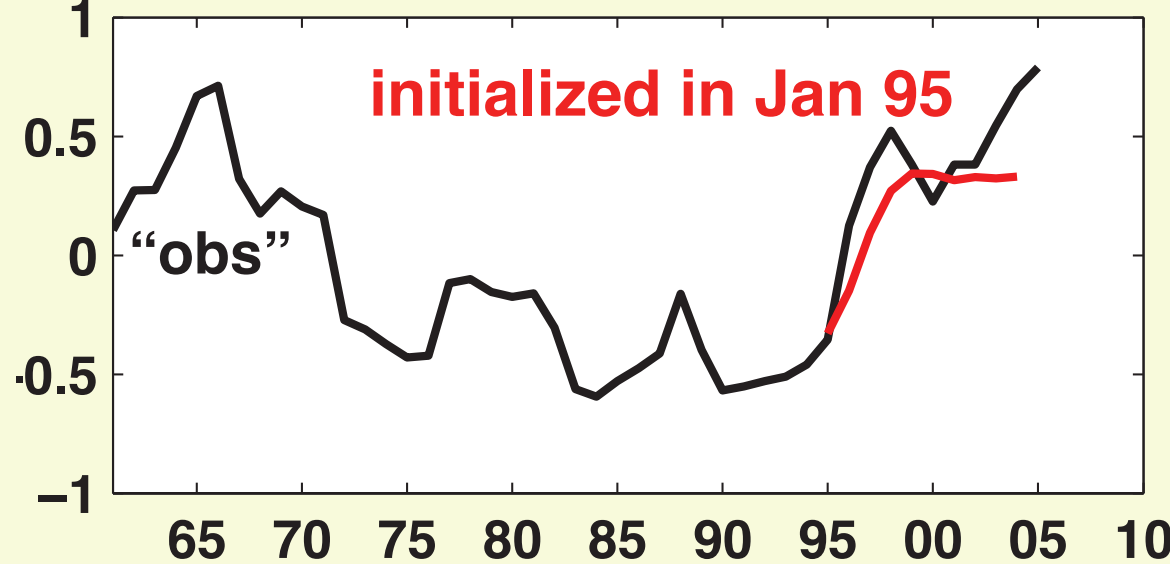


Upper 600m OHC anomalies
(seasonal cycle removed)

Unsuccessful predictions

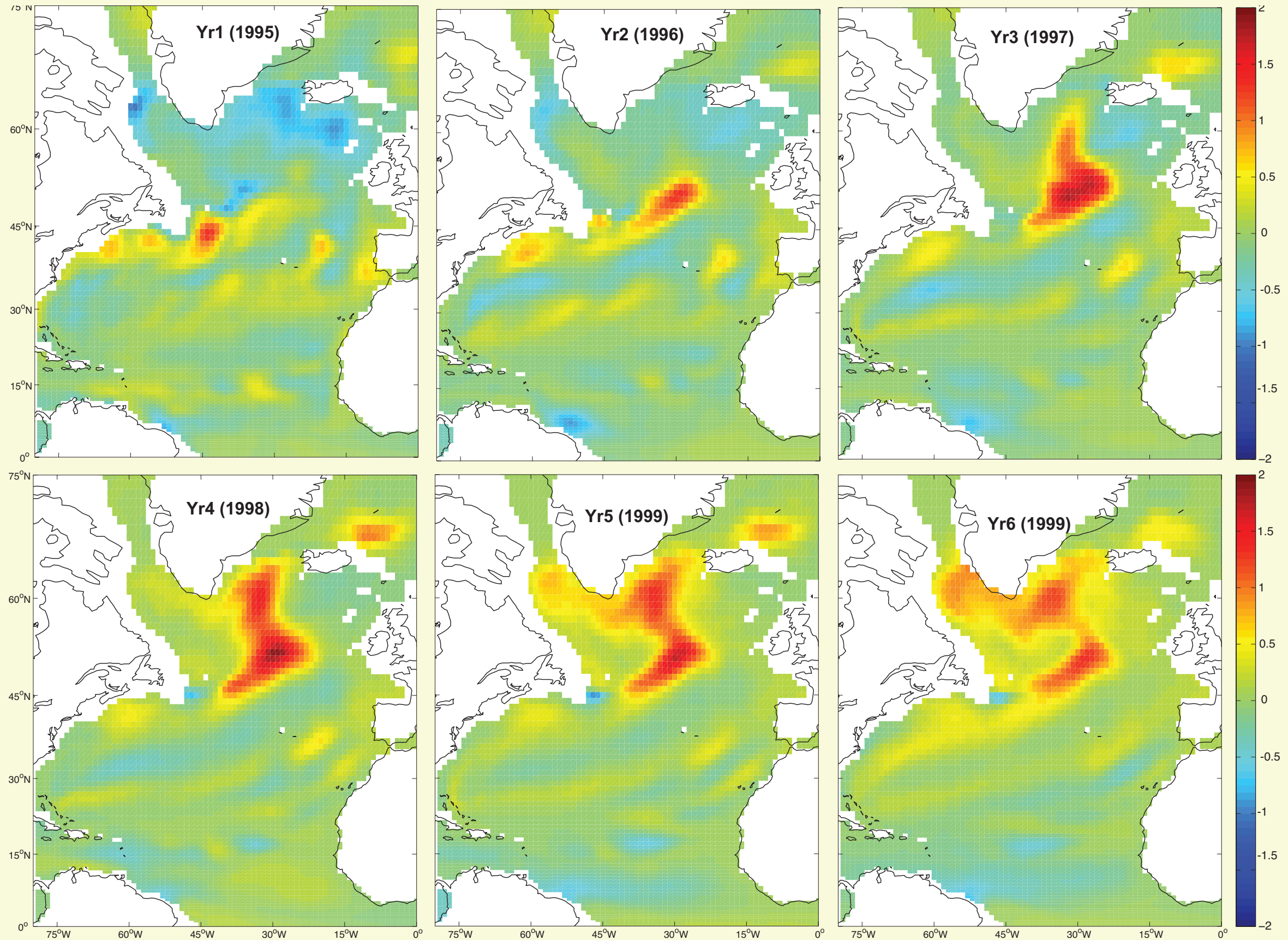


Quite successful predictions



Successful prediction in 1995. Do we get it for the right reasons?
Why aren't the other predictions successful?

Predicted OHC after the 1995 initialization

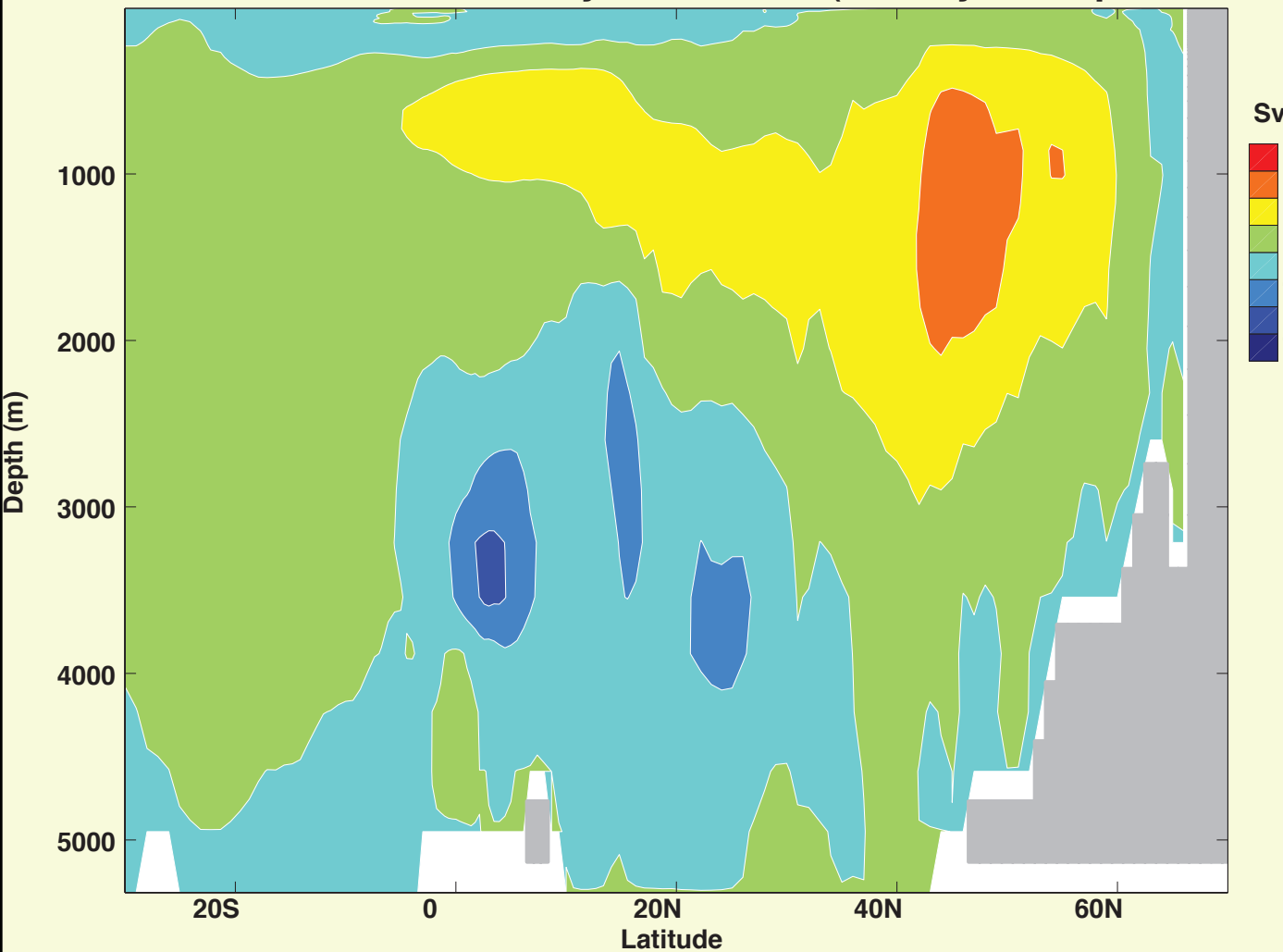


**OHC evolution suggests advection from subtropics.
AMOC-driven?**

Msadek et al. (2012, in prep.)

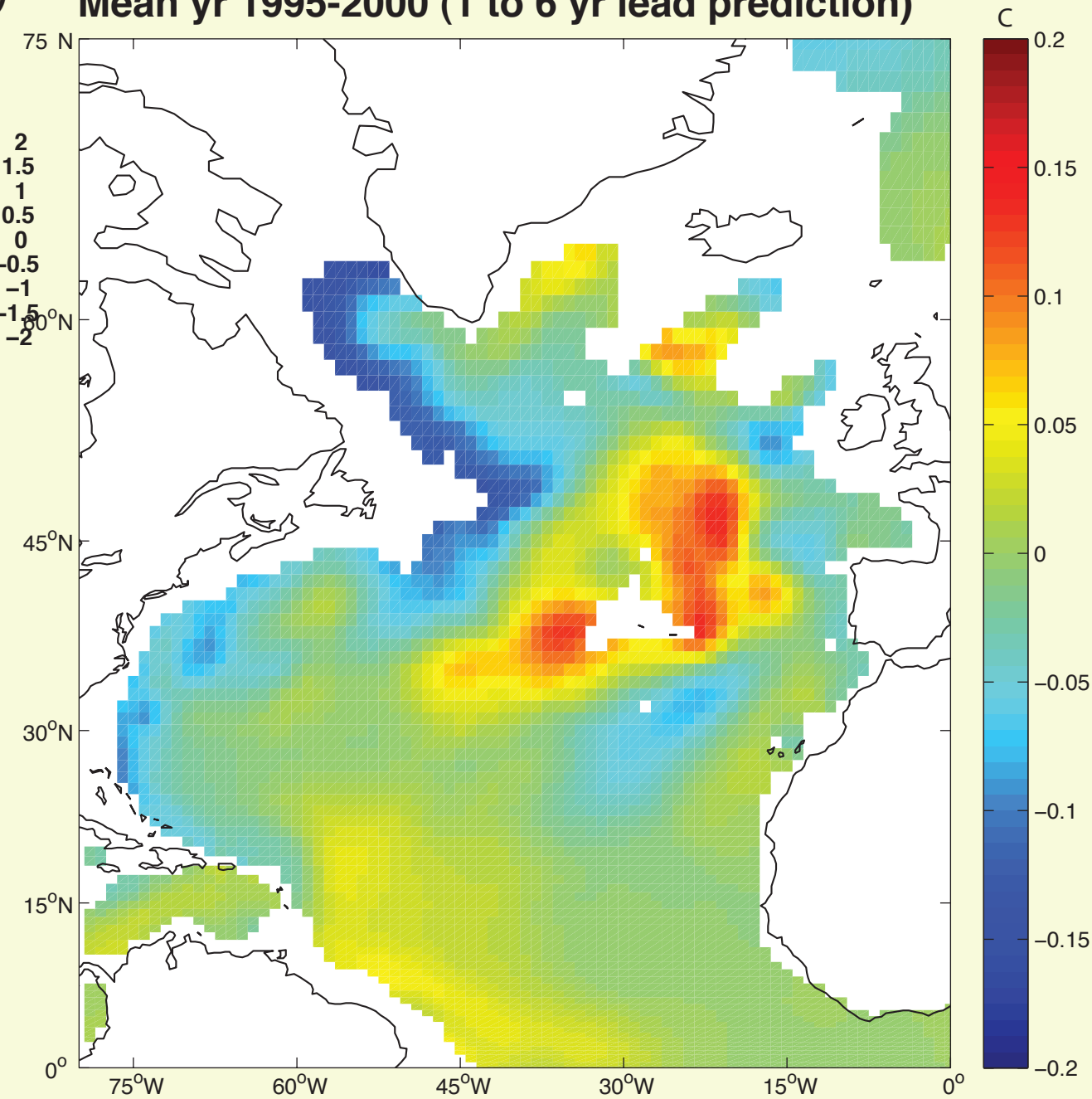
Dynamical response to the AMOC

MOC initialized in 1995. Mean yr 1995-2000 (1 to 6 yr lead prediction)



Anomalous AMOC predicted after the 1995 initialization and southward propagation of AMOC anomalies

Deep temperature (1000-2500m) initialized in 1995
Mean yr 1995-2000 (1 to 6 yr lead prediction)

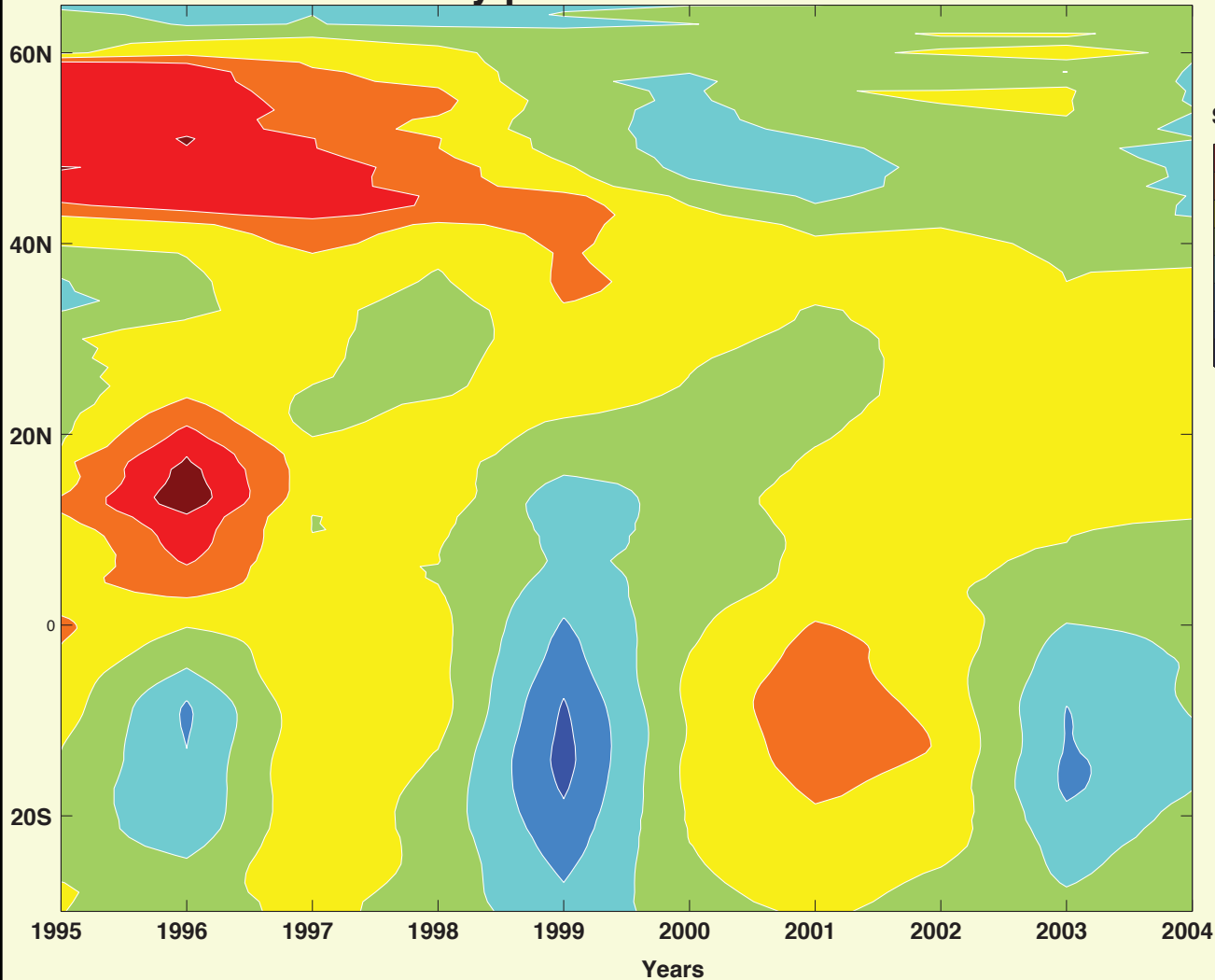


The predictions show cold anomalies at depth propagating along the DWBC: enhanced Labrador Sea water formation

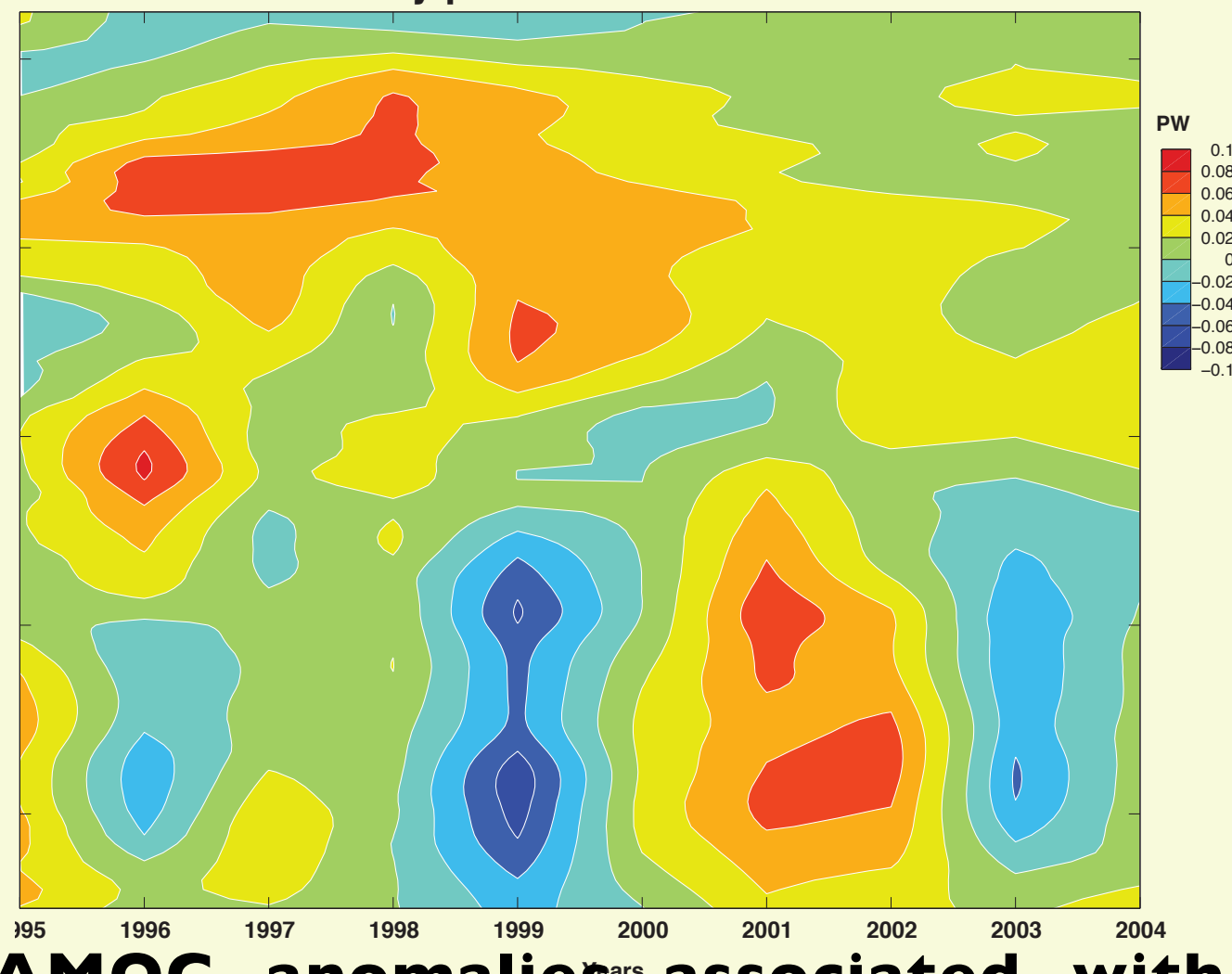
Only for 1995 start

Dynamical response to the AMOC

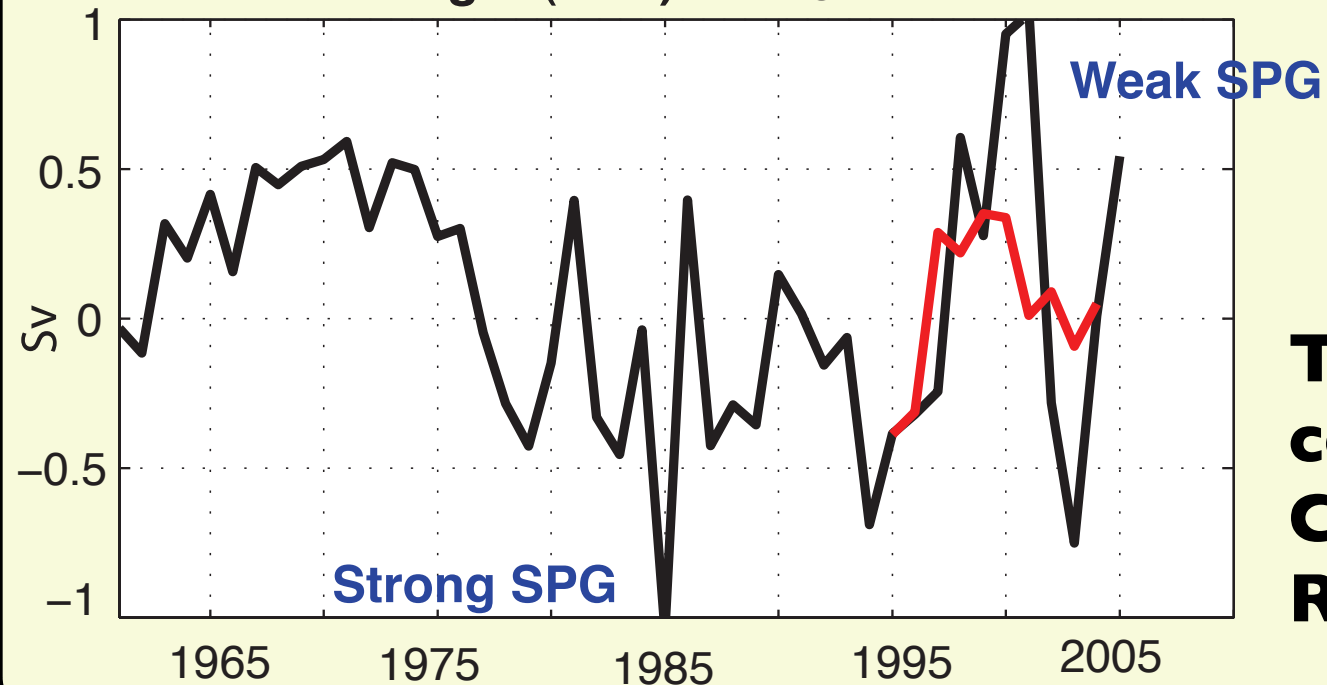
MOC anomaly predictions initialized in 1995



MHT anomaly predictions initialized in 1995



SPG strength (BSF) ECDA init 1995



AMOC anomalies associated with enhanced transport of heat (and salt) northward

Weakening of the SPG predicted by the post-1995 forecasts

This climate shift was predicted with a comparable mechanism in two other CMIP5 models: Yeager et al. (2012), Robson et al. (2012)

Any predictive skill in the tropical Atlantic?

Statistical/Dynamical model for hurricane predictions

Vecchi et al. (2011)

Run Hi-Res AGCM in many different climates. Count storms.

Build statistical model of the response of hurricanes in AGCM

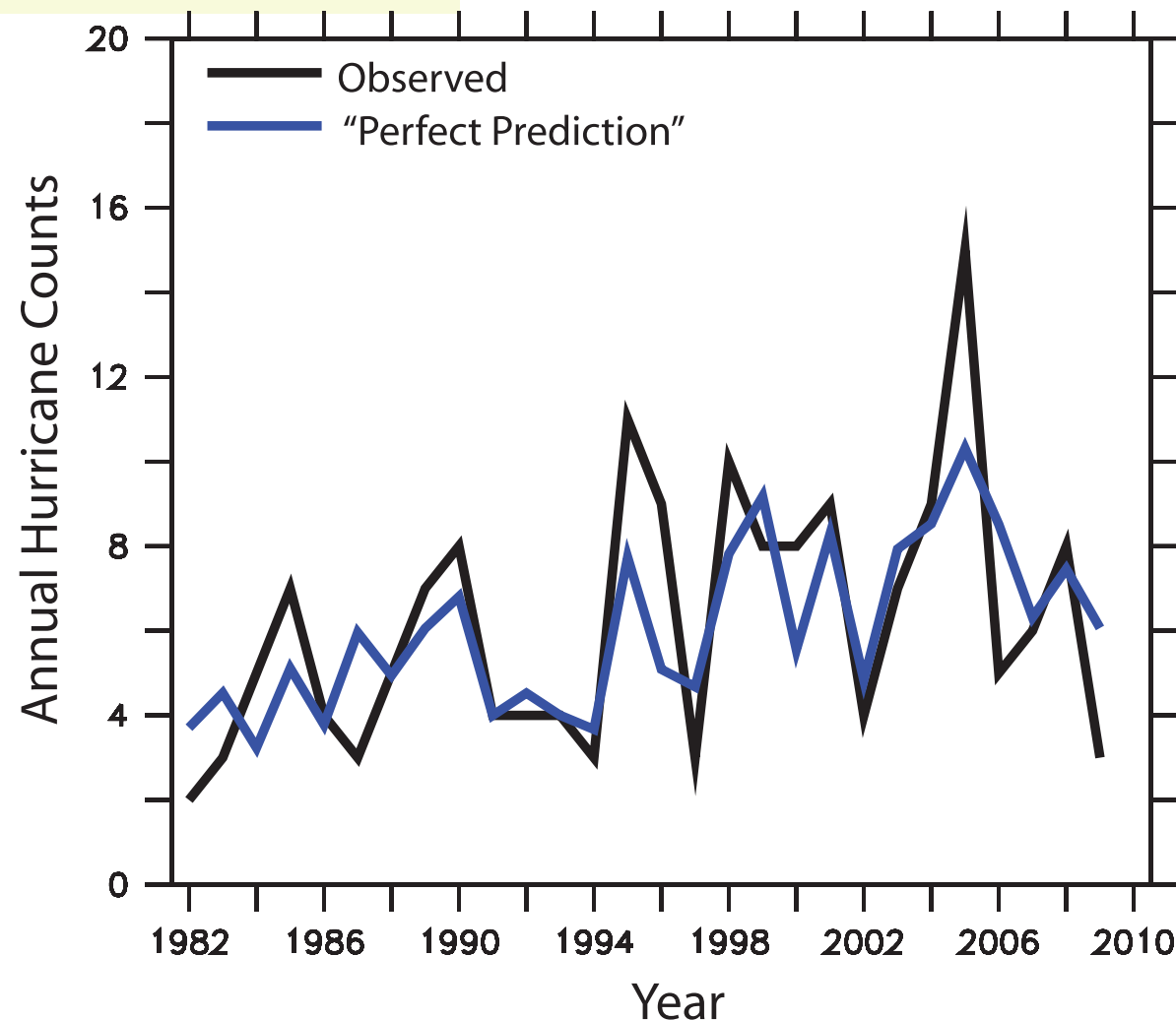
Use climate model to forecast future values of Atlantic and Tropical SST

$$\lambda = e^{a + bSST_{MDR} - cSST_{TROP}}$$

$$\lambda = e^{1.707 + 1.388SST_{MDR} - 1.521SST_{TROP}}$$

Apply stat model to Predicted SST

Make Prediction of Full PDF of Hurricane Activity

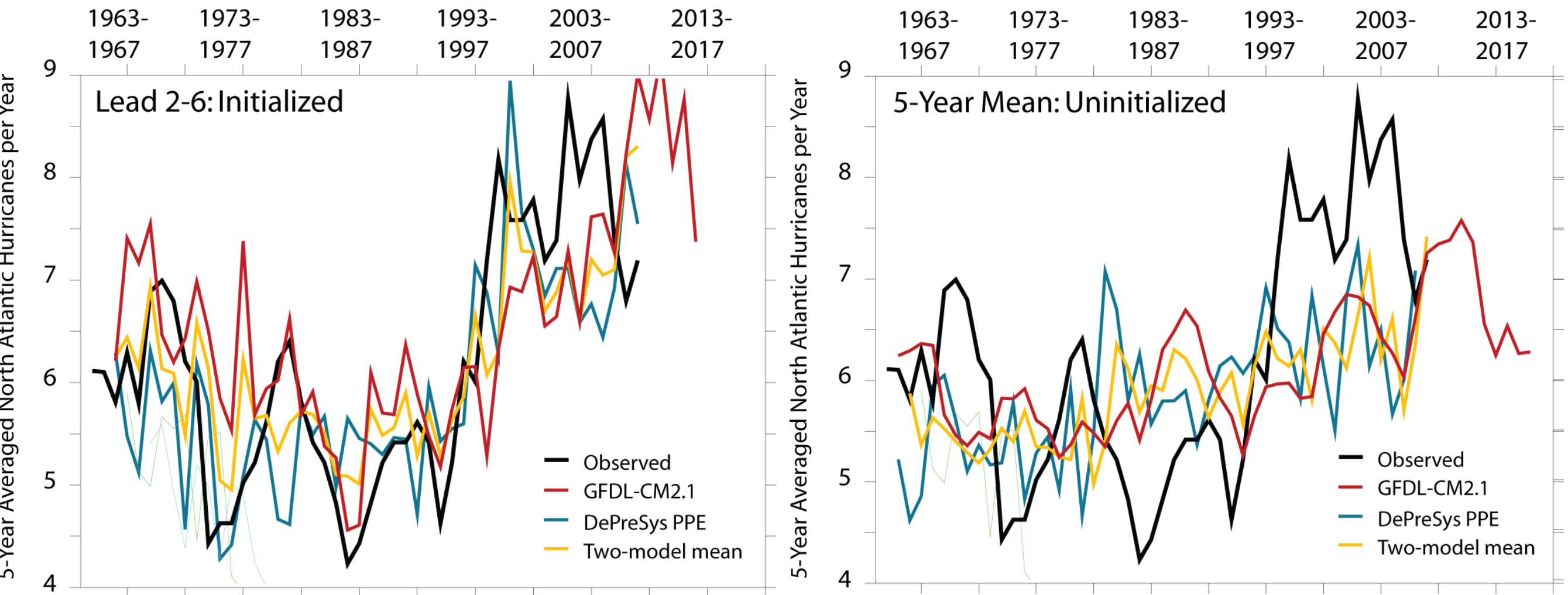


<http://gfdl.noaa.gov/hyhufs>

Courtesy Gabriel Vecchi

Predictions of North Atlantic hurricane frequency in two CMIP5 models

5-yr mean predictions

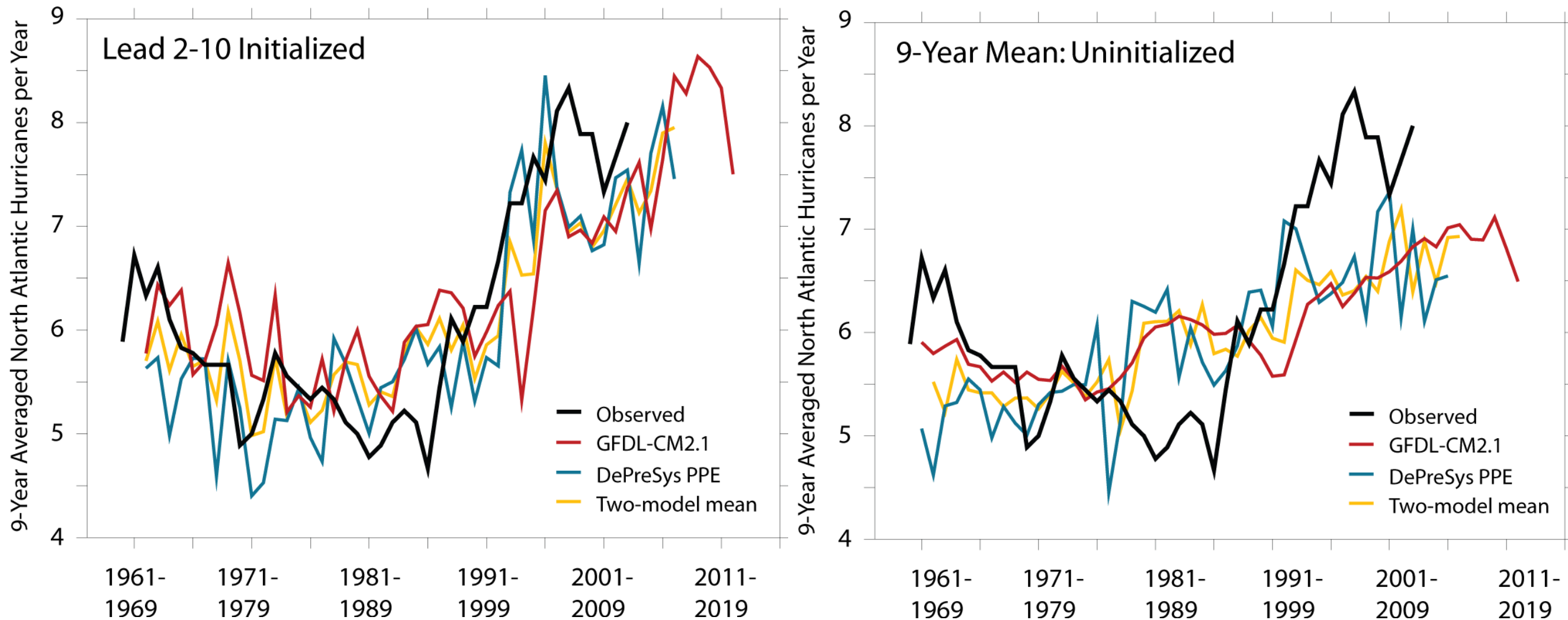


We use the same model as Smith et al. (2010), DePreSys, but different storm counts, and we add GFDL predictions. Could be generalized to more CMIP5 models in the future

Retrospective initialized predictions encouraging: qualitatively better than uninitialized

Predictions of North Atlantic hurricane frequency in two CMIP5 models

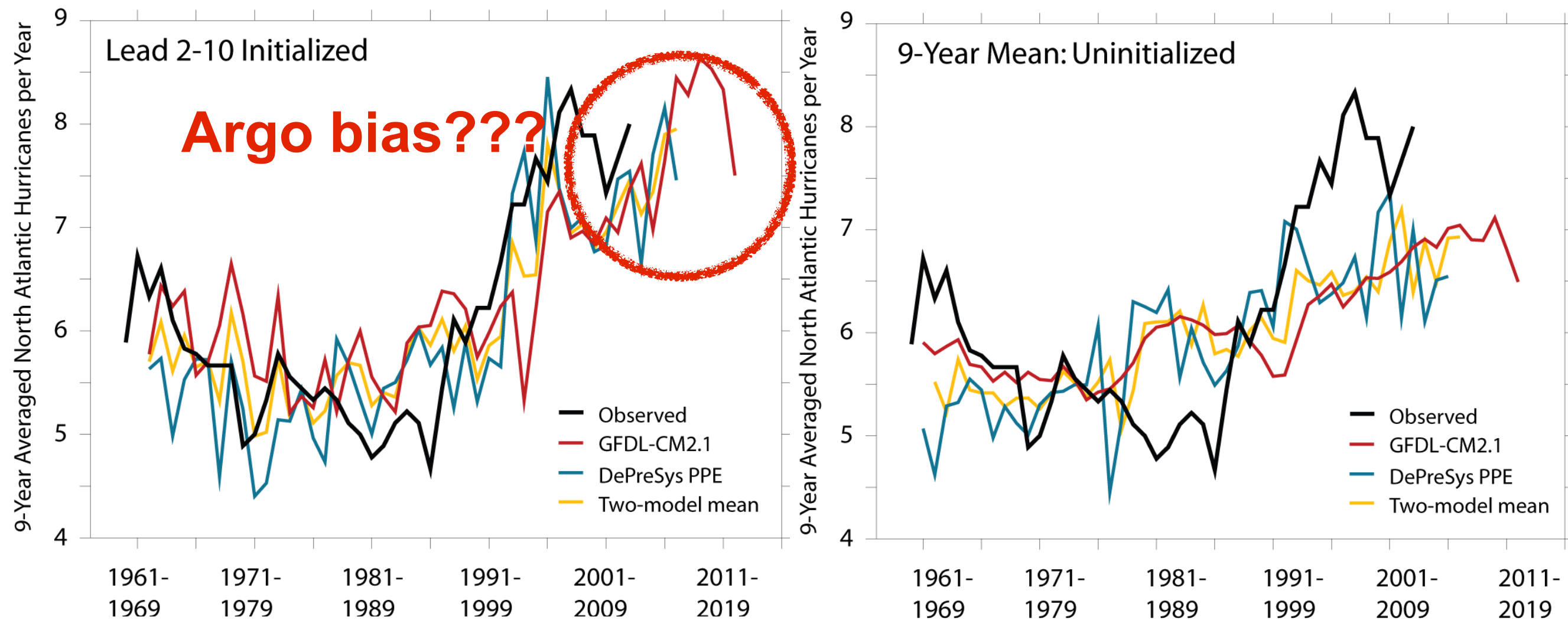
9-yr mean predictions



Retrospective initialized predictions encouraging: qualitatively better than uninitialized

Predictions of North Atlantic hurricane frequency in two CMIP5 models

9-yr mean predictions

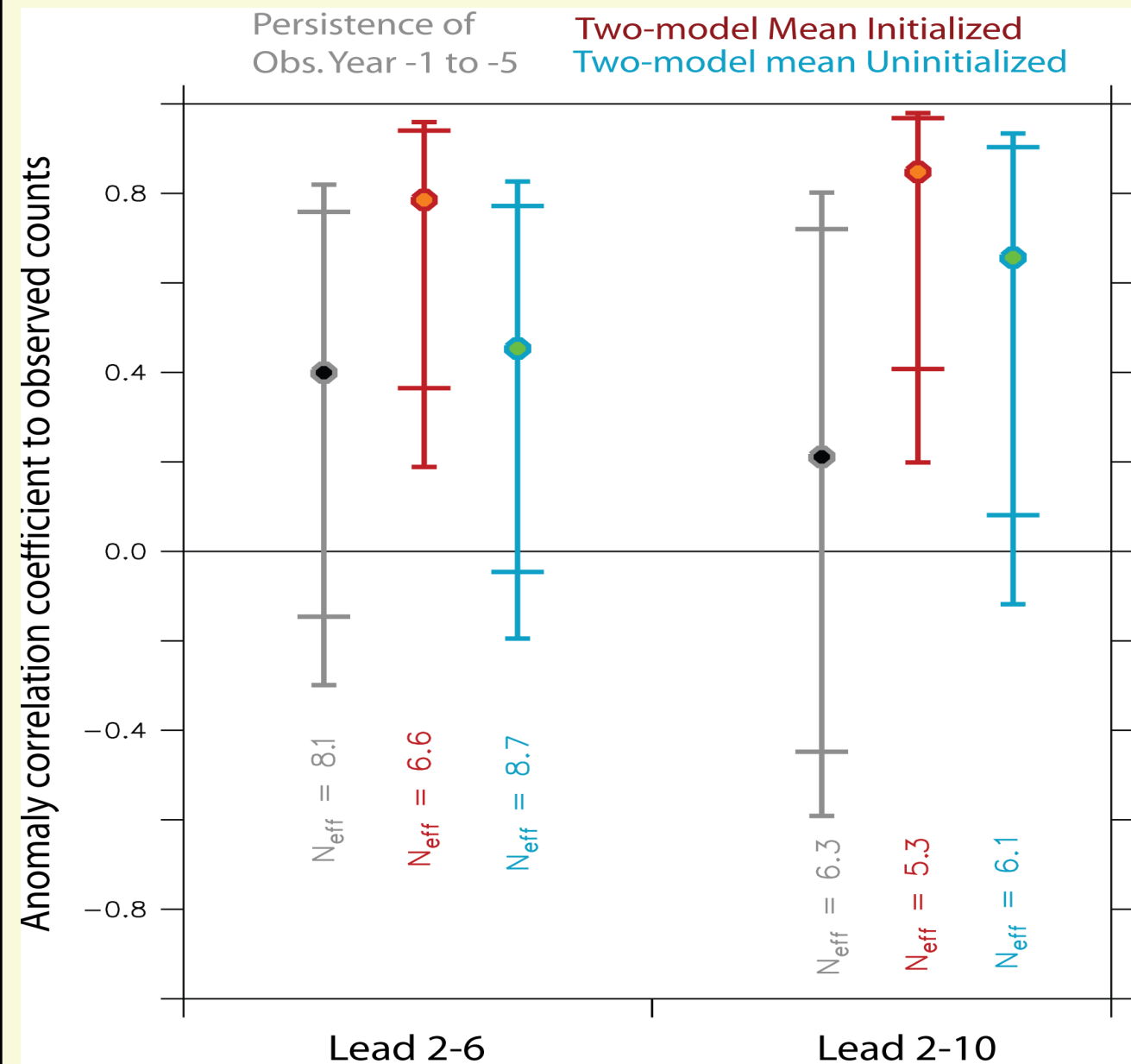


Retrospective initialized predictions encouraging: qualitatively better than uninitialized

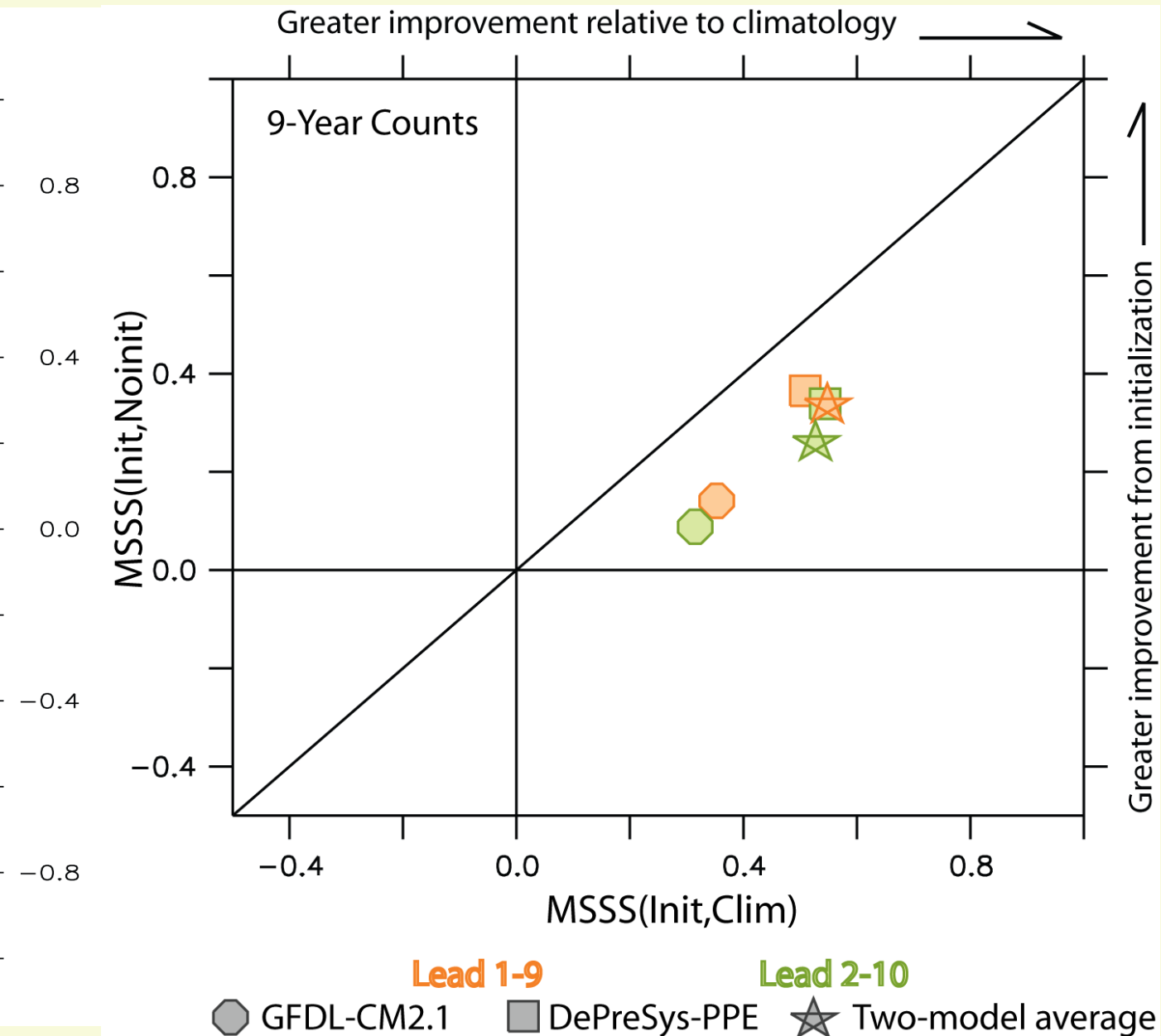
Spurious increase after 2003: change in observational system induced changes in the lead-dependent climatology

Predictions of North Atlantic hurricane frequency in two CMIP5 models

Anomaly Correlations



Mean Squared Skill Score



Retrospective predictions encouraging, but small sample size limits confidence

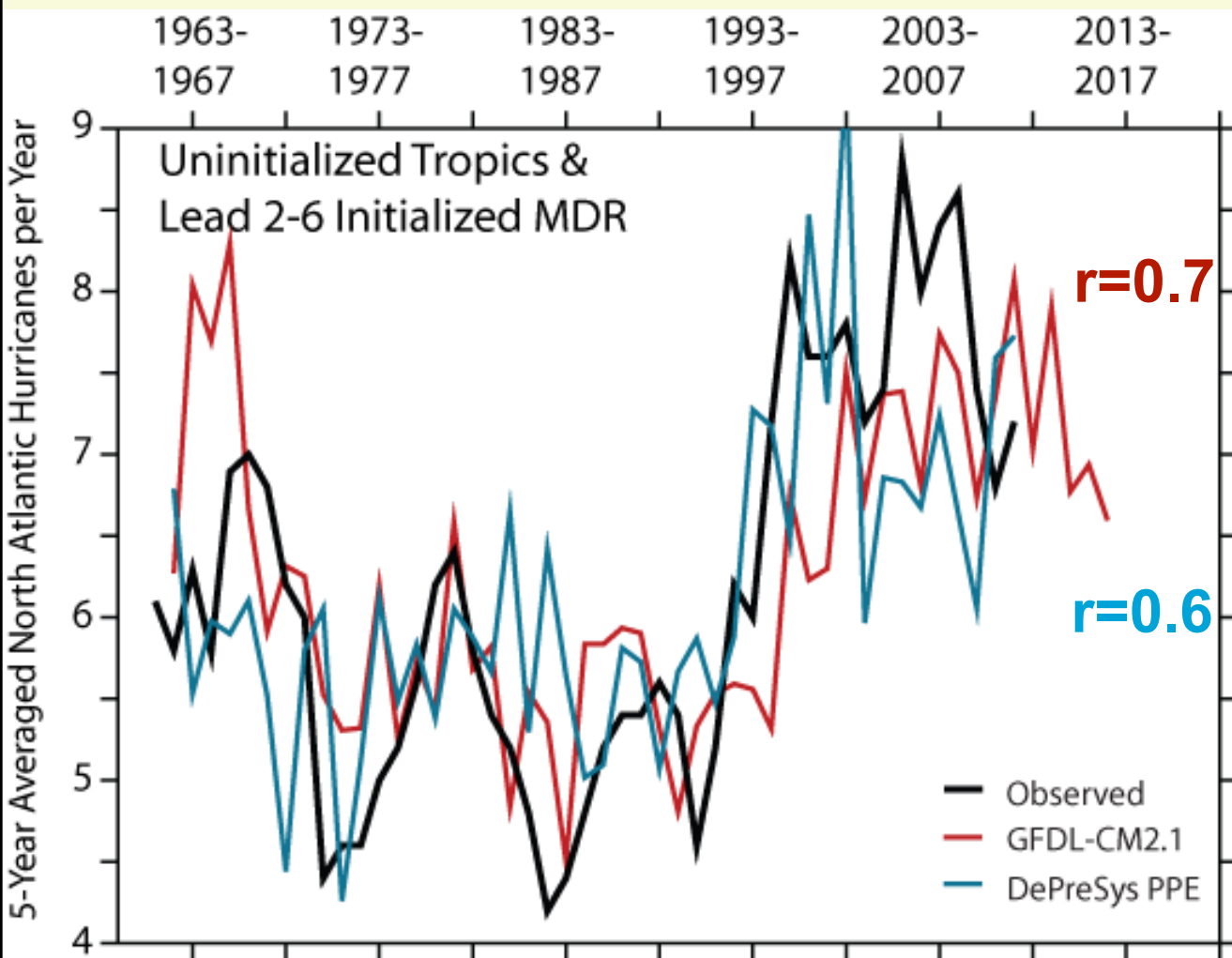
=> Very few effective degrees of freedom

Highest skill for the two-model average

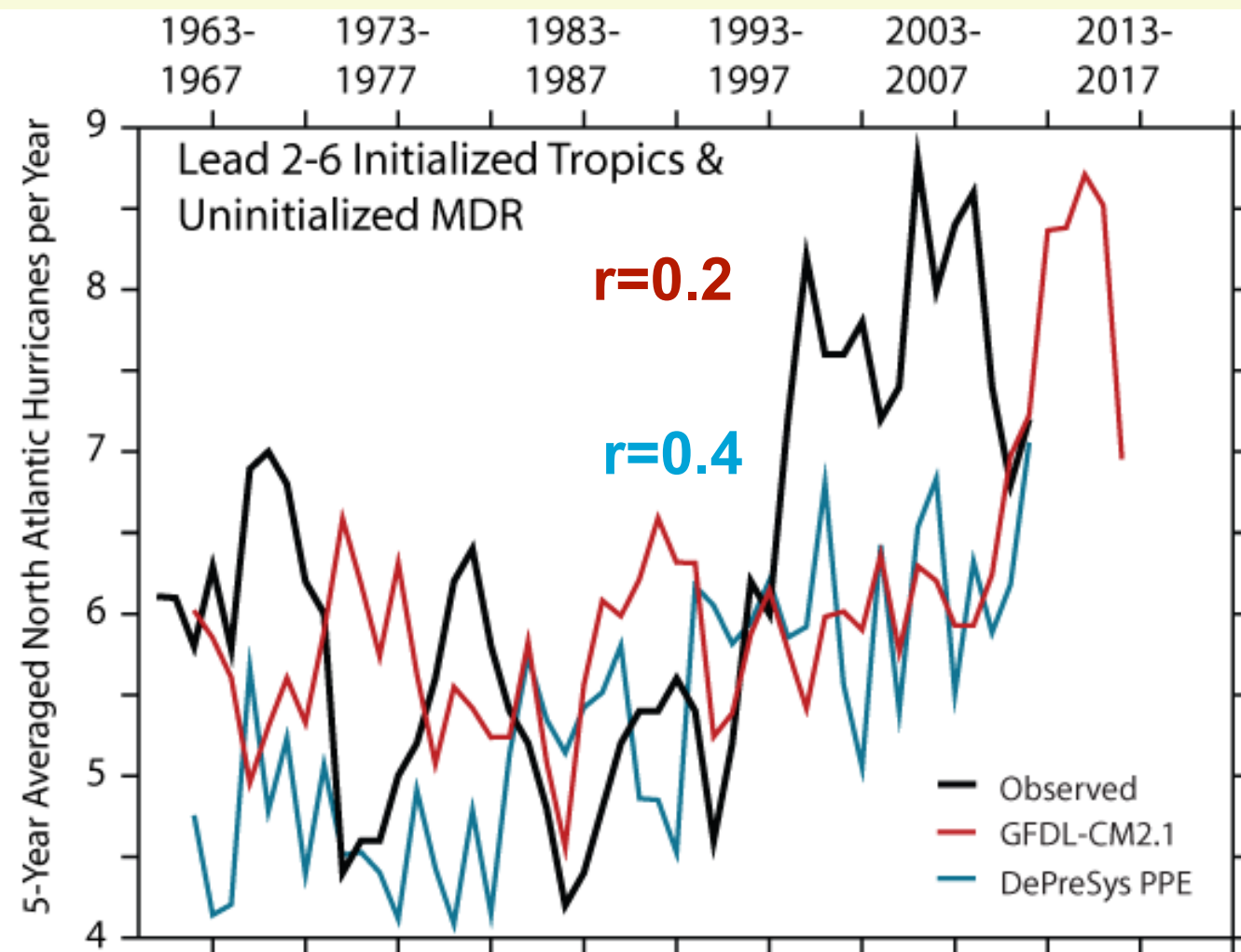
Results consistent with Smith et al. (2010) except the confidence interval and the interpretation of skill

Vecchi, Msadek and coauthors (2012, under rev.)

Where does the skill come from?



Impact of SST Atl. MDR

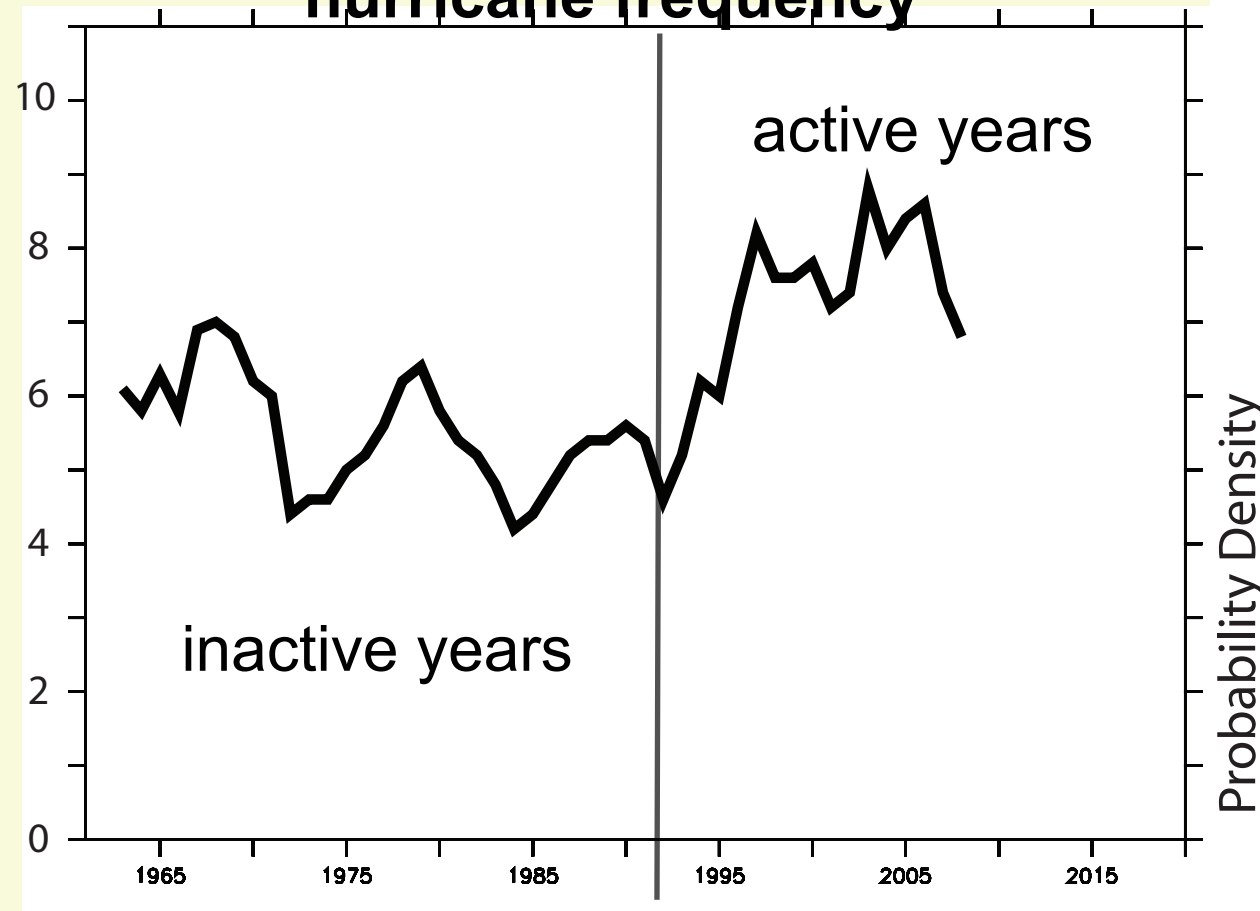


Impact of SST tropical mean

Nominal improvement results from better representation of Atlantic MDR when initializing the models with observations. Natural variability? Forced response?

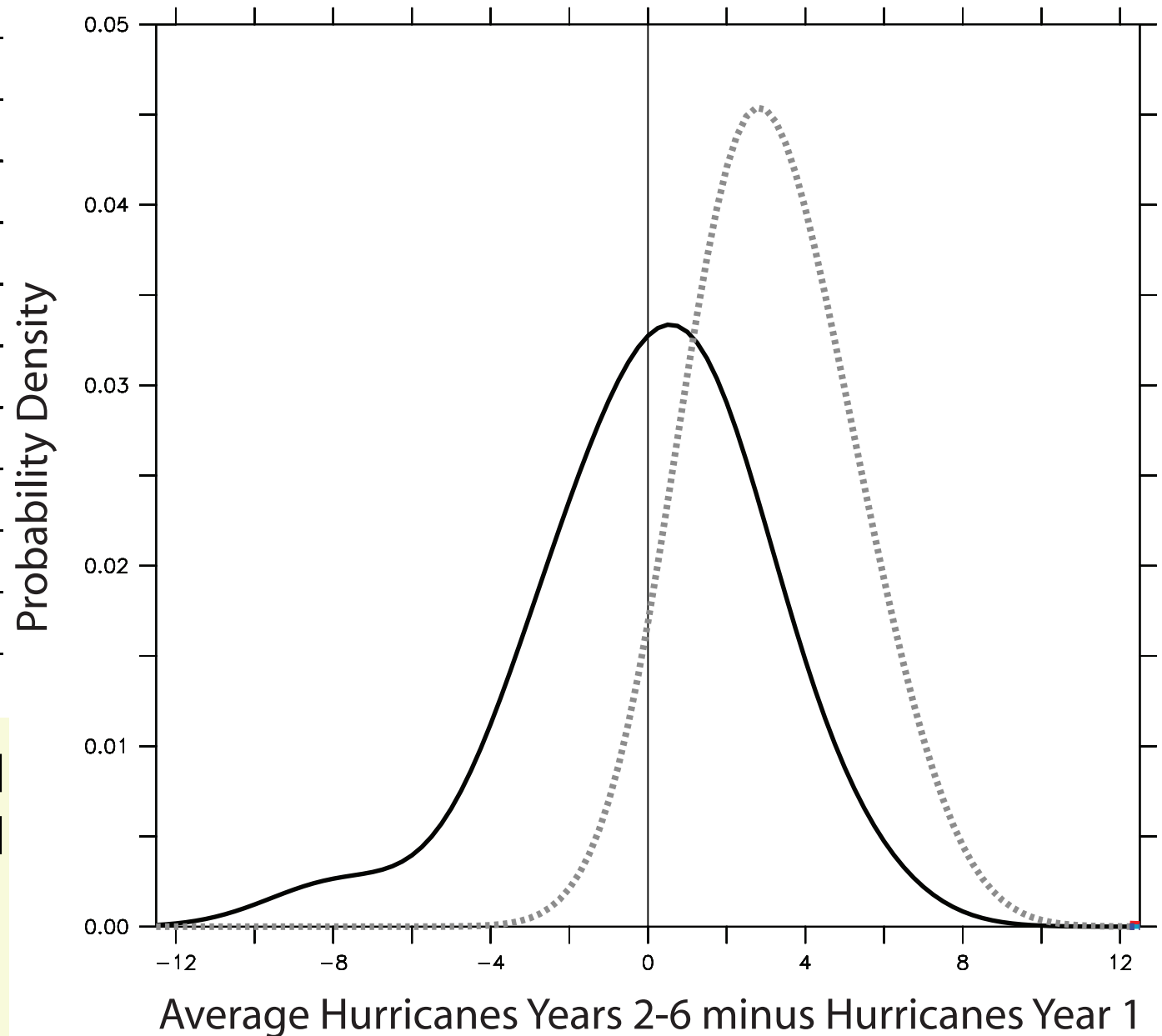
Where does the skill come from?

Observed North Atlantic hurricane frequency

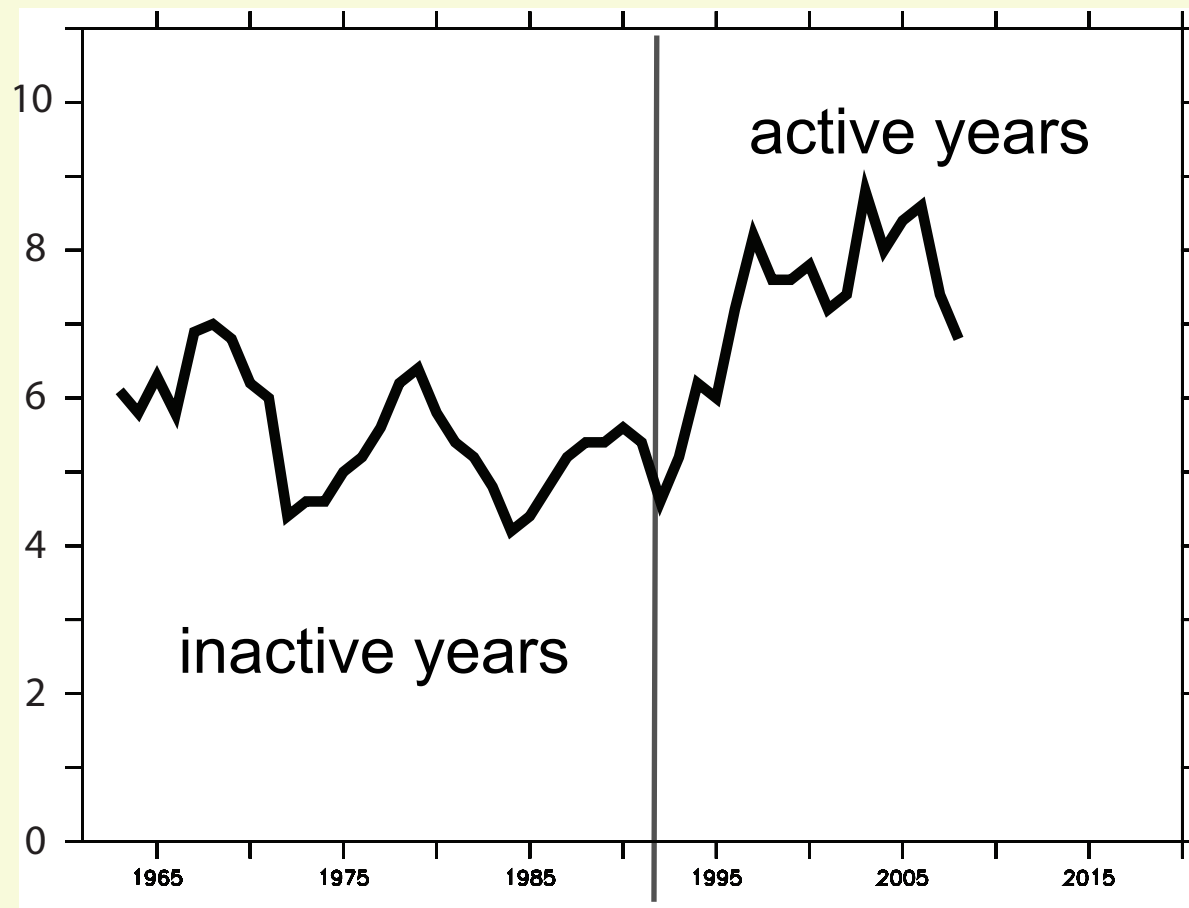


Decadal observed variability dominated by the trend that arises from the mid 90's change point.

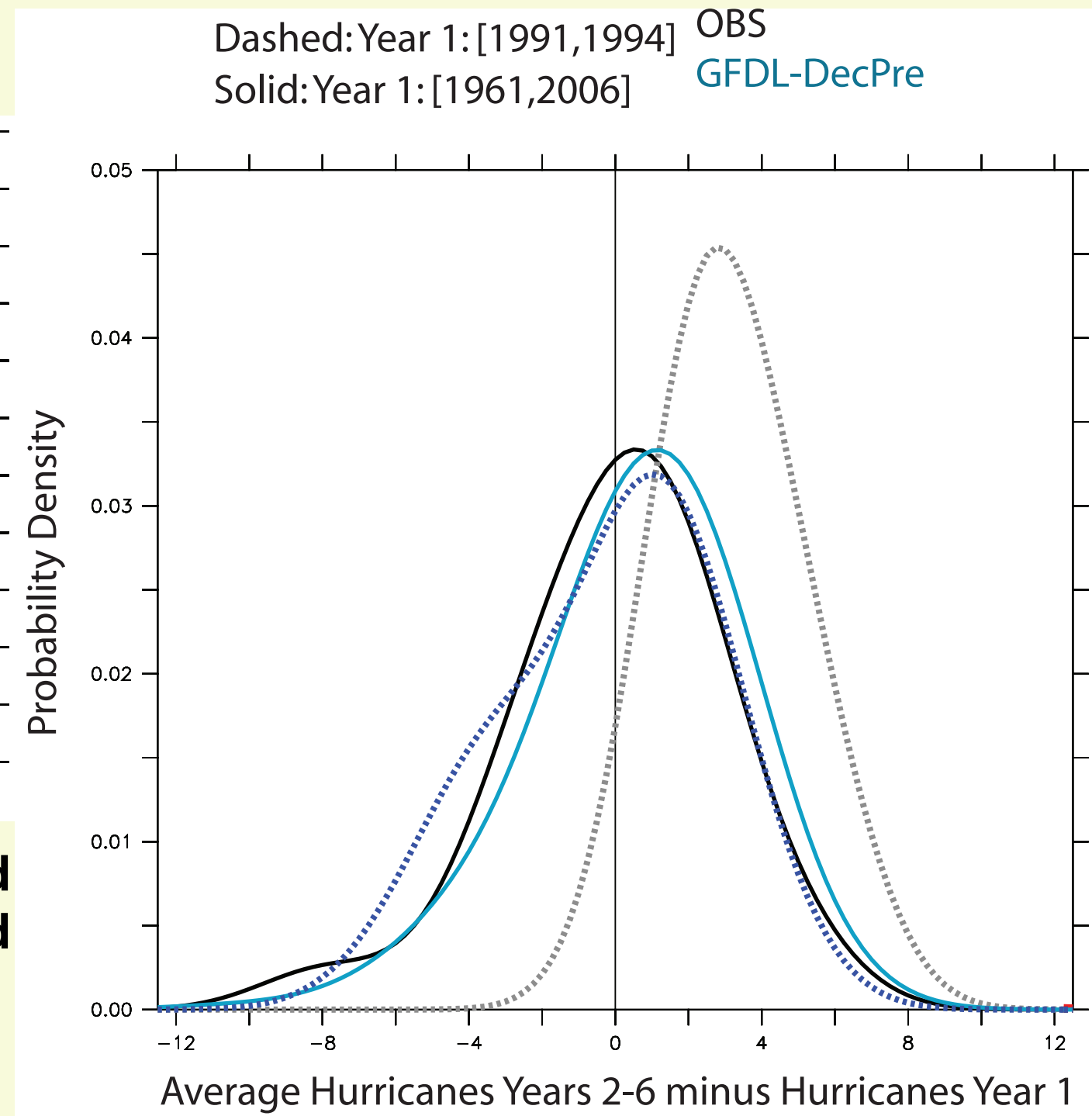
Dashed: Year 1: [1991,1994] OBS
Solid: Year 1: [1961,2006]



Where does the skill come from?

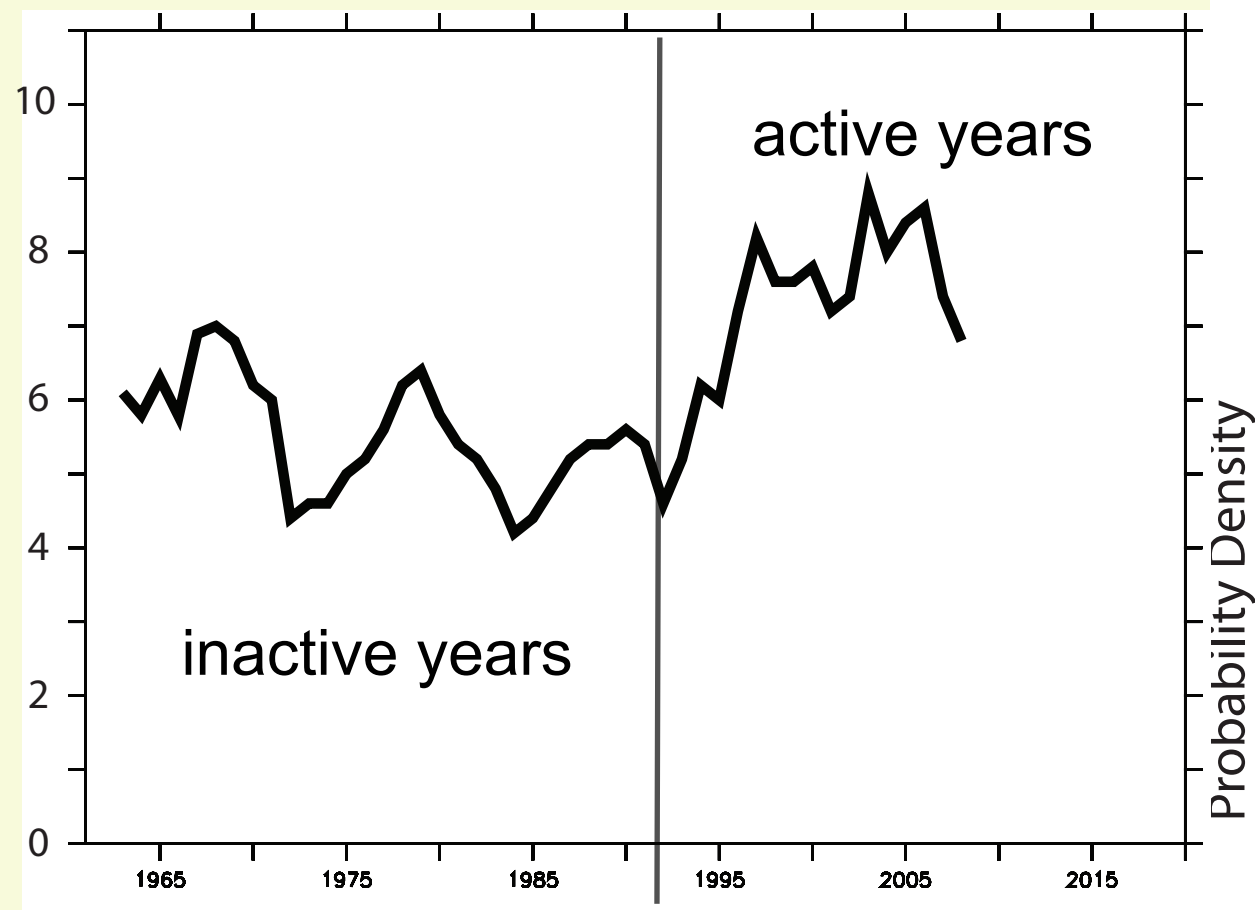


Decadal observed variability dominated by the trend that arises from the mid 90's change point.

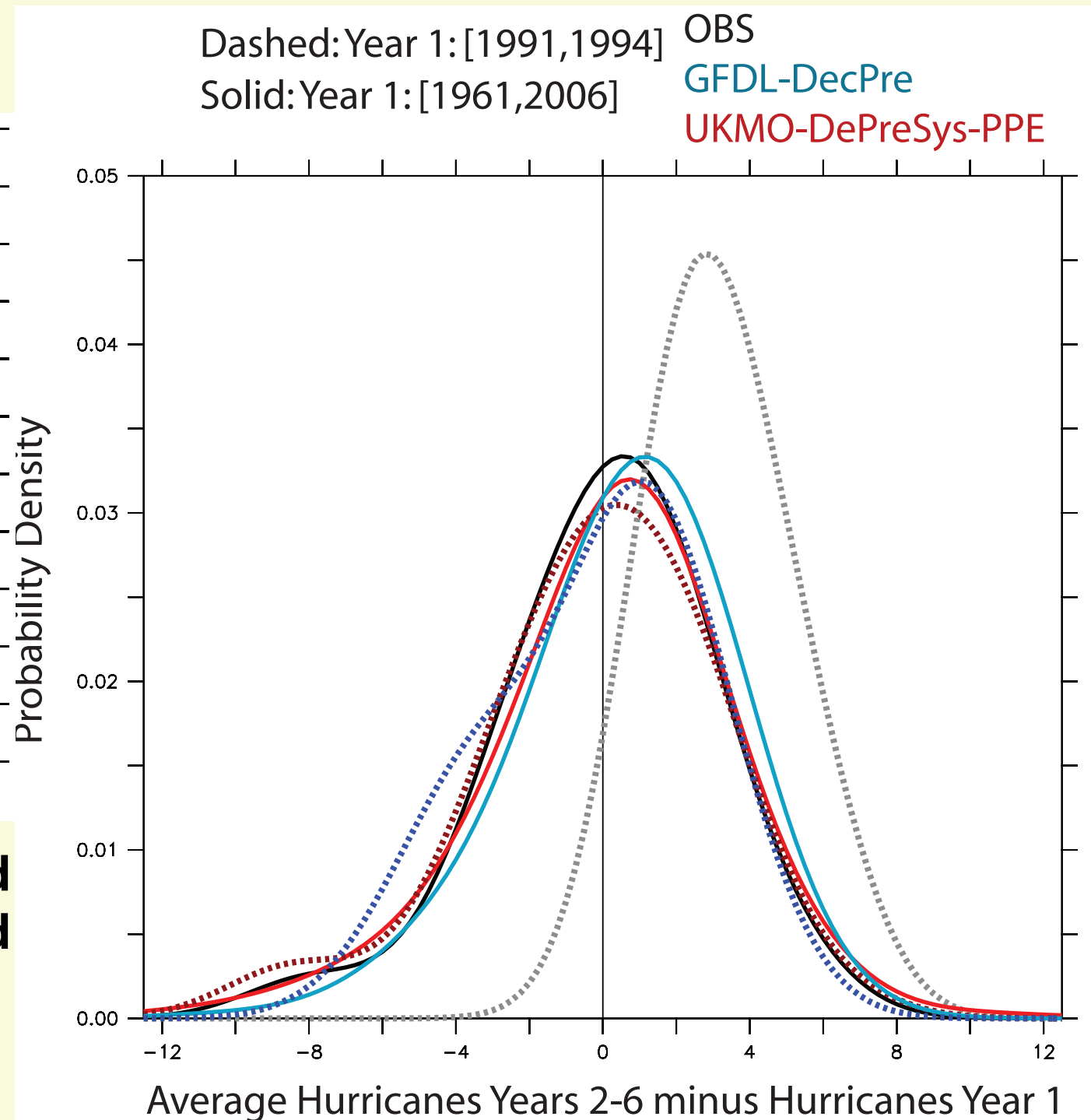


The models do not dynamically predict the 1994-1995 shift but rather persist it

Where does the skill come from?



Decadal observed variability dominated by the trend that arises from the mid 90's change point.



The models do not dynamically predict the 1994-1995 shift but rather persist it

=>Implications for future forecasts: won't be as good as retrospective predictions unless a change point of similar character happens and we can predict it

Summary

-The Atlantic region shows predictive skill beyond the trend: additional skill from natural variability

-Looking at case studies, we can assess whether the skill in retrospective predictions could translate into future skill

The North Atlantic subpolar gyre 1995 shift appears to have a dynamical origin involving oceanic variability (AMOC). Potential skill in future forecasts

-Encouraging results are found for multi-year predictions of North Atlantic hurricane frequency but the models are not able to predict the shift in advance: limited skill for future forecasts. Source of skill not well identified yet.

Looking at other CMIP5 models might help better understand the mechanisms and identify the uncertainties

Challenges

-Challenge to define a climatology with a non-stationary observational system. The introduction of Argo after 2000 may have changed the character of the drift.

-Initializing the deep ocean could be needed for better predictions if the AMOC is a source of skill

-Assessing skill requires observational record for verification for all key variables

=> Decadal predictions are at an infant stage but provide a valuable opportunity to test and improve climate models used for longer-term projections

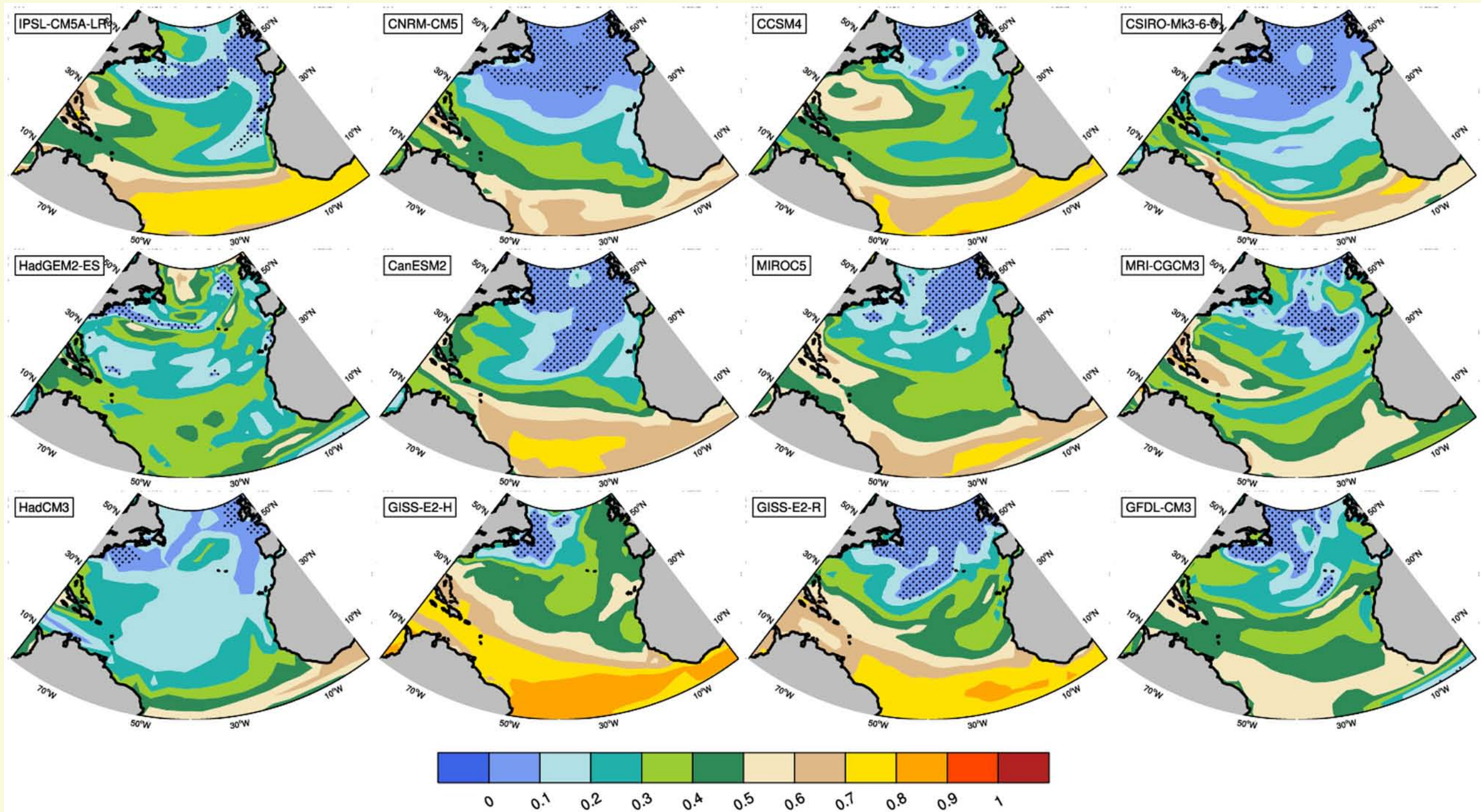
Additional Slides

Other CMIP5 results

Internal variability is the main driver of subpolar NA SST changes in the CMIP5 projections. Strongest signal to noise ratio likely to be found there

Forced variance/decadal variance

Terray (GRL, 2012)



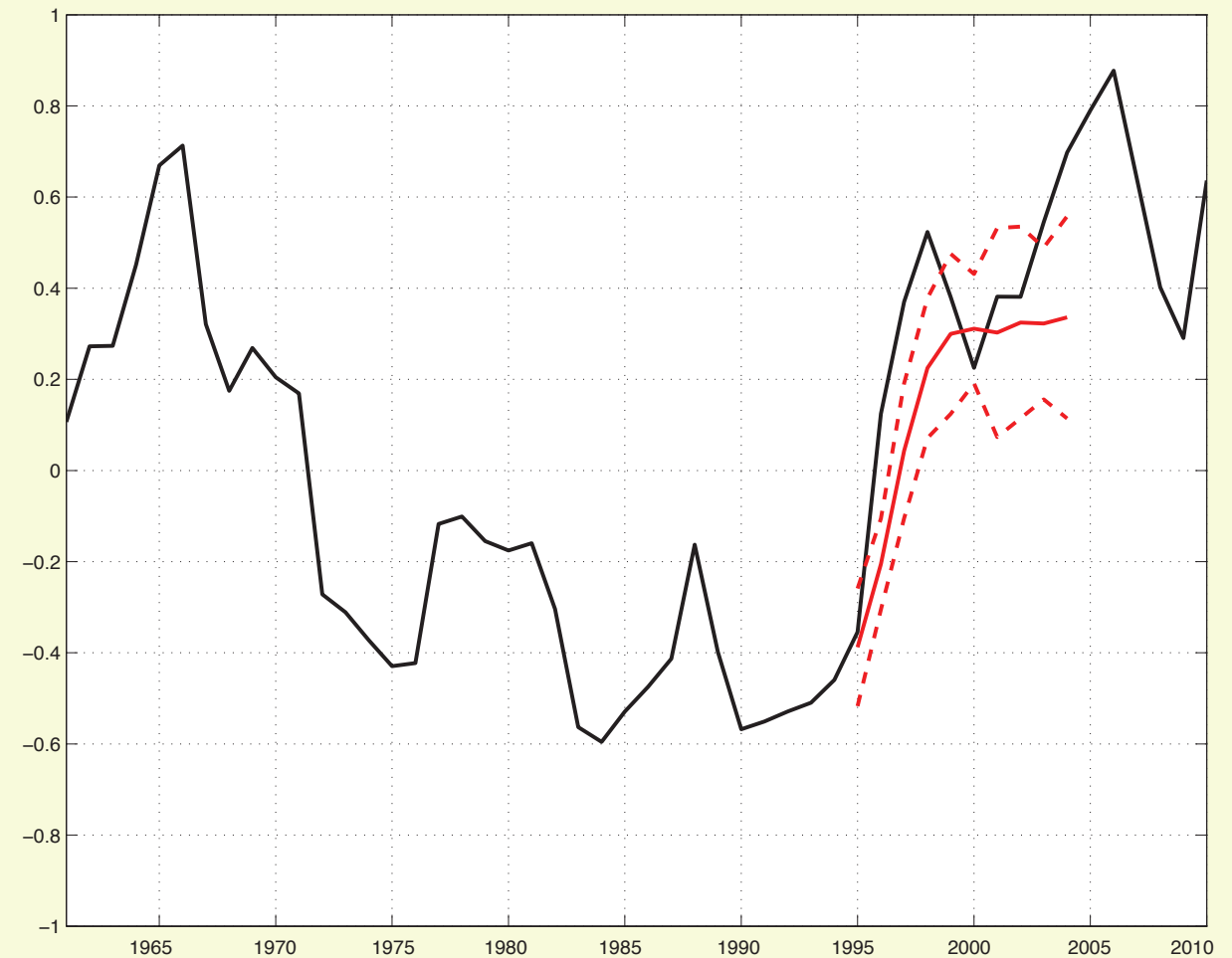
See also Ting et al. (JOC 2009, 2012)

Reliability: Do the observations lie between the predictions spread?

Spread of 95 OHC predictions



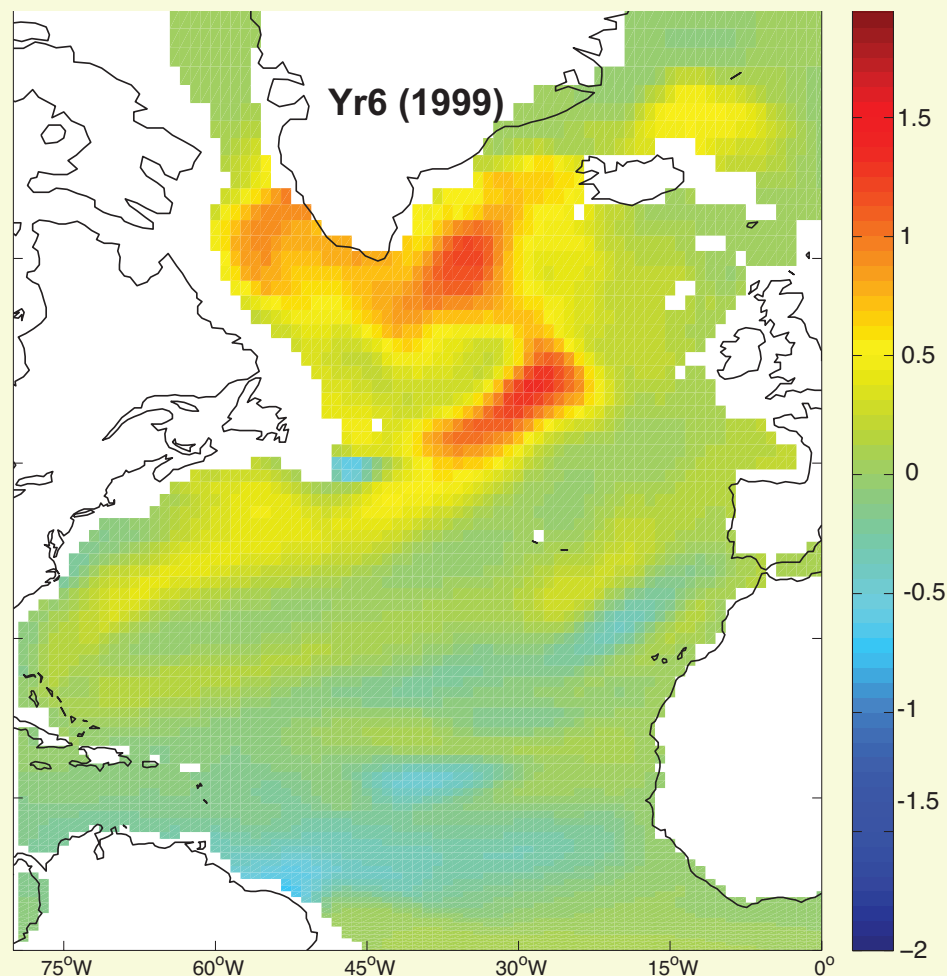
Std



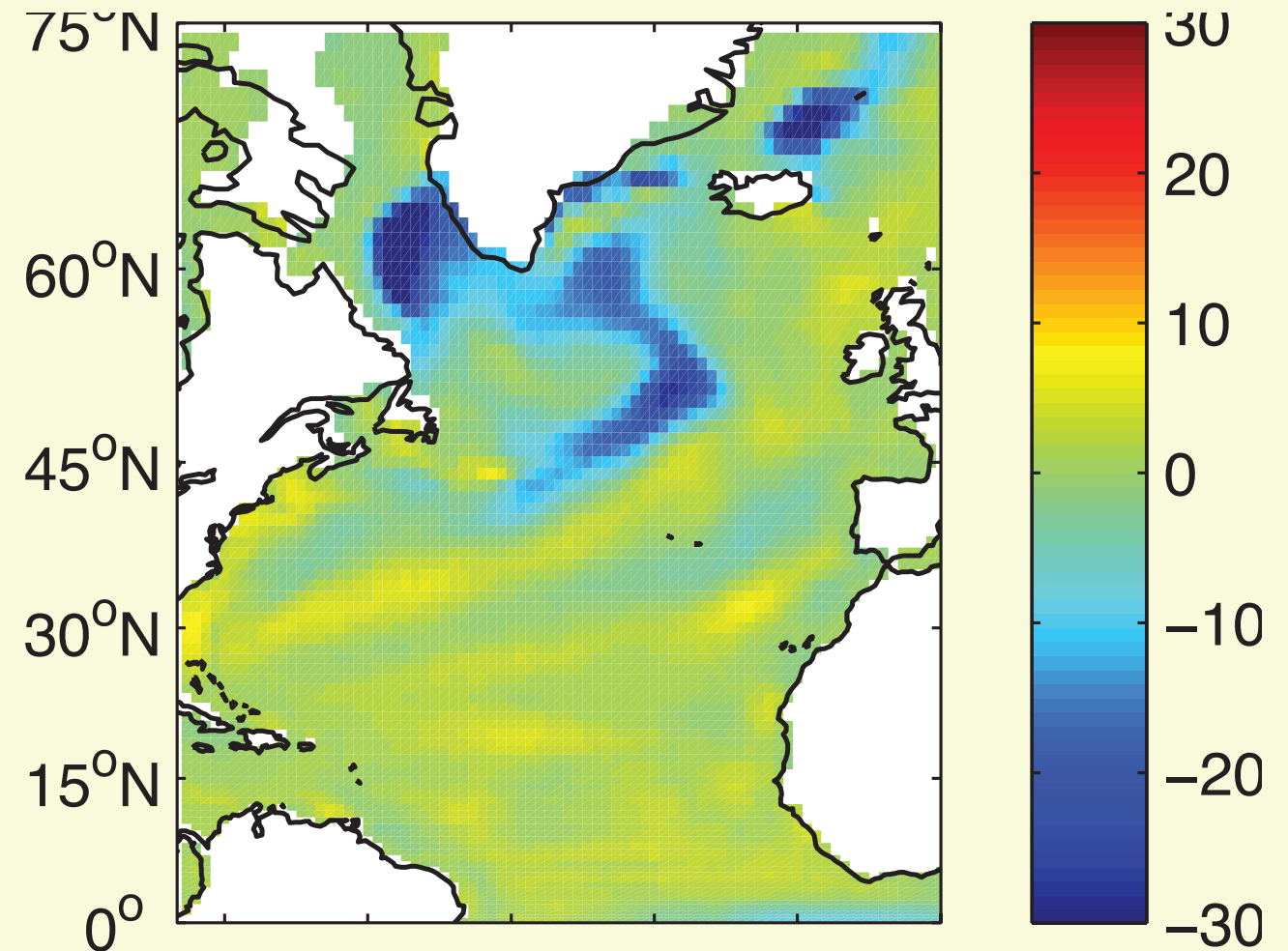
Can it be because the NAO switched sign in 1995 and the warming is just the response to NAO-Qfluxes?

No

**OHC predicted 6 yrs after
1995 initialization**



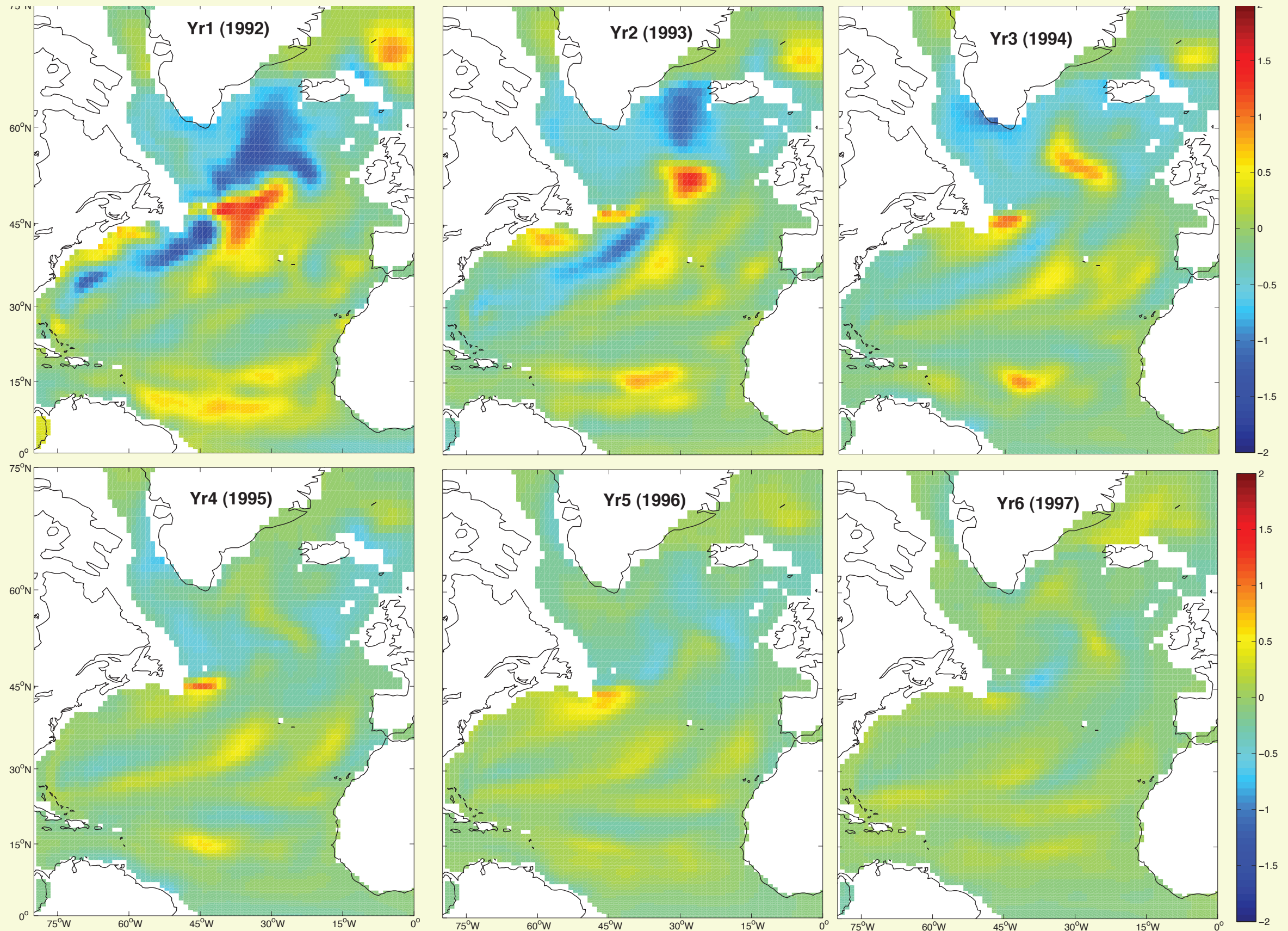
**Qflux predicted 6 yrs after
1995 initialization**



Surface heat flux damps the warm anomalies, does not create them

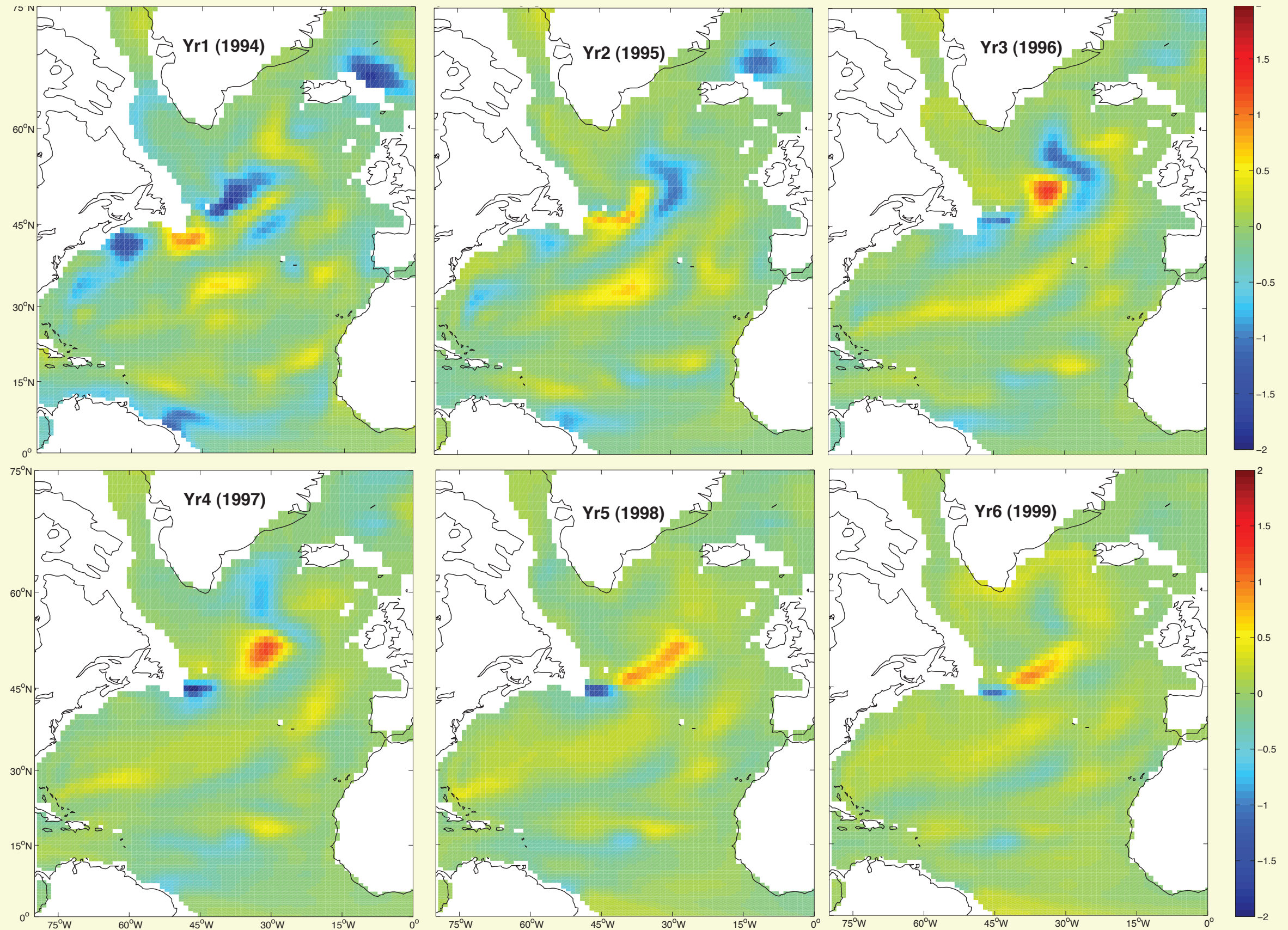
**Same at all lead times following
1995 initialization**

Predicted OHC after 1992 initialization



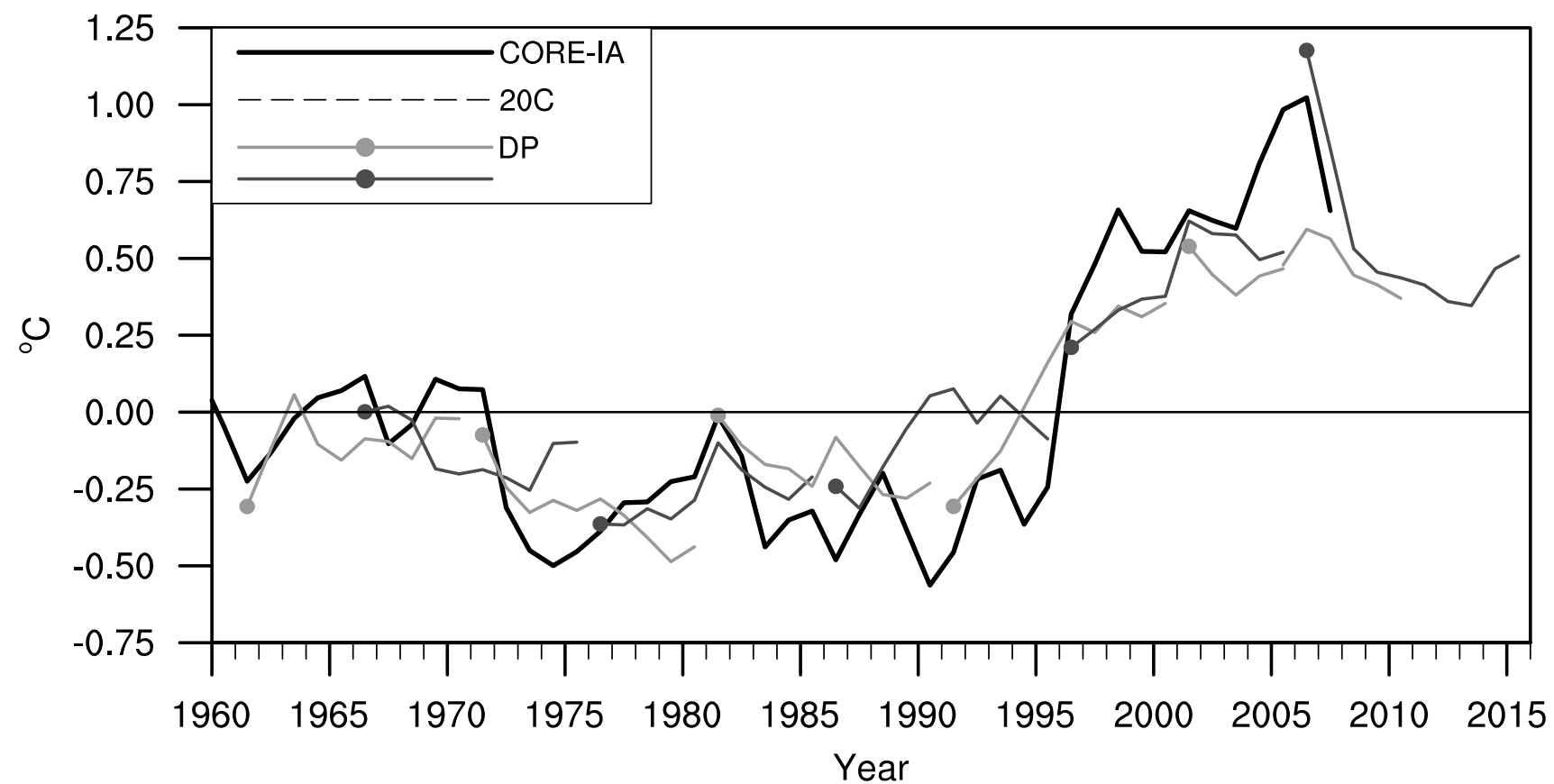
No sign of large-scale warming in the other predictions initialized before 1995

Predicted OHC after 1994 initialization



No sign of large-scale warming in the other predictions initialized before 1995

OHC prediction in the NCAR model



Yeager et al. (2012)